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FOOD TECHNOLOGY

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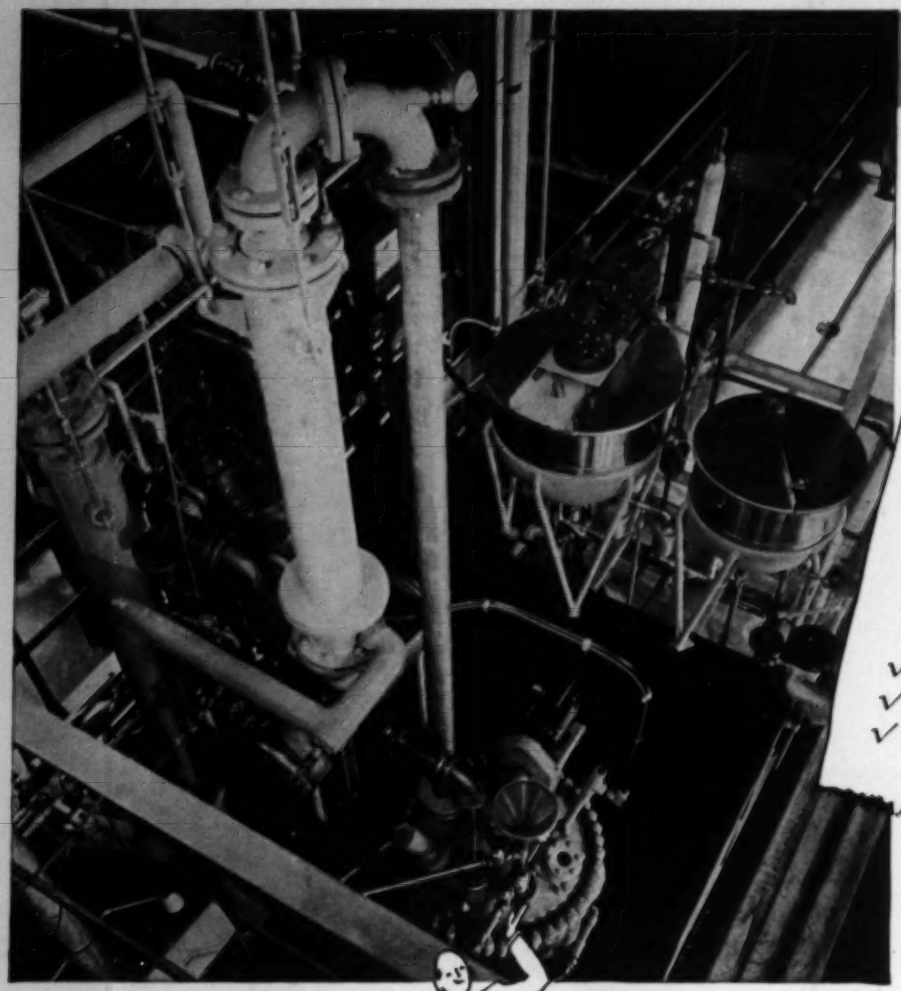

Above: Pfaudler stainless steel kettles (top right), stainless steel heat exchanger and glass-lined reactor with accessory equipment for food research work.

TYPICAL FOOD INSTALLATIONS PFAUDLER HAS ENGINEERED

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- ✓ Fruit Juices
- ✓ Tomato Juice, Puree, etc.
- ✓ Dairy Plants
- ✓ Ice Cream Plants
- ✓ Beverage Plants
- ✓ Brewing Stock Houses
- ✓ Mayonnaise and Salad Dressings
- ✓ Extracts
- ✓ Meat By-Products
- ✓ Syrup, Concentrates, etc.

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As part of its service to the Food Industries during the past 50 years, Pfaudler has furnished not only the equipment for the process but frequently engineered the complete job. As a result of this experience in numerous branches of the industry, Pfaudler now offers a complete engineering service.

In meeting such demands, Pfaudler utilizes materials of equipment construction that best meet requirements . . . glass-lined steel, stainless steels (and other alloys), steel, etc. In fact, Pfaudler is one manufacturer experienced in the production and fabrication of all such materials.

The equipment now manufactured and coordinated with other types, includes open and closed kettles of many designs, vacuum evaporators of large and small capacity, heat exchangers, mixers, fillers, storage tanks, percolators, cookers, etc. Wherever possible, *standard* Pfaudler designs are used. Thus, you obtain established performance at low cost. Take advantage of this experience on *your* next problem!

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THE PFAUDLER CO., ROCHESTER 3, NEW YORK

Engineers and Fabricators of Food Processing Equipment

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The Food Technologist in Relation to Advanced Engineering in Food Processing Equipment*

Any marked advance in the design and construction of equipment for a given food processing operation or product will often involve changes in operation that will affect the character of the finished product. It may improve it; or damage it; or, it may not alter it at all.

It is very dangerous to make a radical change in equipment or its operation on a full production scale without first determining by laboratory and pilot scale tests how the change is apt to affect plant procedures and quality of product. After the data from such preliminary studies are in hand it is also essential to closely follow the behavior of the food product when processed on a commercial scale with the new equipment of advanced engineering design. In other words the engineer and the food technologist should cooperate.

It might be well at this point to mention some of the possible hazards and problems that might arise when advanced food engineering is applied in a food processing establishment; and indicate some of the advantages of advanced engineering from the technological point of view. The new advanced equipment may give a lower yield of product; for example, a peeling machine of revolutionary design might peel potatoes and apples too deeply; a new rice polishing machine might lose too much of the kernel in the polishings. It might lower quality in some manner; for example a fruit grader of new design might have tremendous capacity but bruise or lacerate the fruit. If it is a heat treating device it might sterilize the product but not inactivate enzymes (until the technologist has determined what changes in operation are needed), or, it might inactivate enzymes and sterilize, but tend to scorch the product by local overheating. If it uses a special form of energy such as ultrasonic vibrations, X-rays, or ultraviolet rays, the flavor, clarity, odor or vitamin content of the food may be affected adversely. The new equipment may favor overoxidation. It may be so costly to install that it can never pay its way.

On the other hand there are usually more advantages or benefits than hazards in advanced engineering, because usually the engineer consults the technologist as he is working on his designs and specifications and tries to foresee and eliminate objectionable or hazardous features. The advanced equipment often speeds production at lower cost by conserving man power and mechanizing operations. It often results in better quality, as did flash pasteurization of some food products. It often adds greatly to appearance of the plant's production area; witness the gleaming stainless steel equipment in a modern tomato products plant or a mammoth size continuous pressure sterilizer and cooler in a modern cannery. This is good for morale and produces good public relations. Visitors are favorably impressed. It often reduces confusion and excessive manual handling in food processing operations.

Should advanced food engineering be only a problem for the engineer and the technologist? No. Top management, the plant superintendent and often some of the plant's skilled mechanics will all be concerned and consulted. Often top management needs considerable convincing. If the superintendent is invited to cooperate and becomes an advocate of the advanced equipment, the three departments working together will have a better prospect of gaining top management's approval and allocation of funds. Often the technologist or a department foreman or the superintendent has an idea or a hunch for improving a process, a machine or a product, but needs the engineer to design the necessary equipment. The new idea does not always originate with the engineer. But cooperation all along the line is necessary; then it is the project of all and some key man is not trying to sabotage it.

Should the engineer or the technologist or management have the final say as to whether a new and advanced engineering change be adopted? Being a food technologist and not an engineer or manager this speaker favors delegating final decision to the food technologist, chiefly because he is responsible for quality. He must try by small scale experiments to forecast what the new device will do to the quality of his fruit juice, or canned peas, frozen berries or what ever. Likewise since he is responsible for quality control he is concerned as to how the change will affect this phase of his responsibilities. Of course, he must confer with the engineer in arriving at his decisions and make his decisions on an impersonal basis; not merely on whether he thinks the engineer is or is not a good Joe.

Will advanced engineering developments in the food industries make changes in food technologist training desirable? Yes, for the following reasons:

In order that he may fully understand the operation, limitations, capacities, and care of modern equipment, the young food technologist must know more about mechanical and electrical engineering than we old timers were expected to know. This is in addition to thorough training in chemistry, bacteriology, food spoilage, sanitation, waste disposal, food processing operations, and other standard courses useful in food technology. Otherwise he will be handicapped in respect to usefulness and advancement.

The new advanced equipment may so greatly increase the capacity of a processing line that special, rapid methods of checking quality of the product become necessary. The food technologist and his laboratory staff may have to devise these rapid methods or they may receive assistance in such development from State or Federal or commercial laboratories. For example, a new orange juicing machine may have such great capacity that samples must be taken and examined at 15 minute intervals for vitamin C content, total acidity and color, as affected by variation in the raw material. Obviously, quick methods of analysis would be needed.

So, I return to a statement made at the beginning of this talk. The technologist, the superintendent and the engineer must cooperate in planning important advances in engineering to minimize the danger of costly mistakes. In fact the process should be tested by the technologist insofar as practicable before the engineer undertakes his detailed drawings. Also as he proceeds

* Presented before the Ninth Annual I. F. T. Convention, San Francisco, California, July 11-15, 1949.

with his drawings and specifications he should consult with the food technologist who will often be able to suggest changes that will make the machinery more effective or will catch errors that might cause trouble later. In other words team work is essential.

Then after the new machinery is built, set up and put into operation, all hands, including the engineer and the technologist, will cooperate in making the "darned thing" operate efficiently, effectively and economically so that the plant will operate profitably.

An excellent example of effective cooperation by engineers, food technologists and management is the development of the ion exchange technique to purify juice from pineapple waste for the production of a light colored, stable syrup of pleasing flavor for use in canning of pineapple; as described by R. W. Porter in Food Industries, Volume 20, Number 5, pages 85-96, May 1948. Thorough laboratory research and pilot scale production preceded design, construction and installation of the commercial plant. Consequently, when the process was put into production, it worked smoothly and efficiently. W. V. CRUESS.

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These men are the Associate Editors of FOOD TECHNOLOGY.

Since the preparation began for the first issue—that of January, 1947—these men have always responded promptly to requests for assistance, thus making it possible for the journal to be issued regularly, and generally on schedule.

Up to the present time, no one has retired from our Editorial Board; since the first meeting of the Board in 1947, however, the Associate Editors have favored a limited tenure of office for themselves; in 1948, a policy was adopted making the term of office three years, and the policy has now become effective. Accordingly, six Associate Editors, whose names were drawn by lot, as told in the minutes of the 1949 meeting of the Editorial Board, published in the November issue, will retire from the Board on December 31 and six new members will appear on the Board immediately thereafter. Those who will no longer be with us are W. H. Cathcart, H. C. Diehl, L. S. McClung, E. M. Mrak, B. E. Proctor, and P. C. Wilbur.

Those whom we welcome to take their places are E. C. Crocker of Arthur D. Little, Inc.; J. Avery Dunn, of Atlantic Gelatin; M. S. Dunn, of University of California, Los Angeles; D. F. Sampson, of American Can Company; George F. Stewart, of Iowa State College, and C. R. Stumbo of Food Machinery and Chemical Corporation. Dr. J. A. Dunn will take over the assignment of Book Review Editor which has been carried so capably by Dr. Cathcart, and Mr. von Loesecke will be News Editor, taking over this important and somewhat trying assignment from Dr. Proctor who has brought that department to its present position of being one of the most popular in our journal.

In addition to these changes, it is with regret that we announce that a member of the Board is relinquishing his post at the earnest suggestion of his physician. Mr. W. Ray Junk has found it advisable to favor his health by reducing, for the time being, the volume of his responsibilities, which, as all who attended the San Francisco Convention realize, was greater during the past year than any man should carry. As General Co-chairman of the Ninth Annual I. F. T. Convention, Mr. Junk carried much of the burden of putting together one of the finest meetings I. F. T. members ever attended. We have confidence that Mr. Junk, showing in this instance his usual sound judgment in following good advice, will soon become again his normal energetic self.

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Government Meat Inspection in Canada[a]

G. A. ROSE

Associate Chief Veterinarian, Department of Agriculture, Ottawa, Canada

(REVIEW PAPER)

The historical background of food inspection and the objectives and application of meat inspection in Canada are discussed.

Man's habit of looking over the food he eats is not a modern one—it dates back to time immemorial. One of the earliest records of this is to be found in Holy Writ where we read that Moses, the Prophet, ordained the examination of the flesh of animals as an important religious rite. He forbade the eating of meat that had not come from cloven-hoofed ruminants, and even extended this proscription against the consumption of blood and the sinew of the thigh. Likewise, predacious birds, fish without scales, and badly injured animals were considered by him to be an abomination.

The ancient Egyptians, Greeks, Phoenicians, and later, the Mohammedans, also passed laws controlling the consumption and distribution of meat. Although, in many instances, superstition and religious principles undoubtedly governed their actions, there is evidence to support the view that the food edicts of that period were also inspired, partially at least, on hygienic grounds.

Later, during Mediaeval times, attempts were made by the municipalities of some European states, to prevent the sale of obviously diseased or so-called "mangey" meat. A charming little story is told in the Chronicles about one village where all the pigs had to be assembled at the local monastery at an appointed time, to be inspected simply by viewing their tongues! In all probability the monks at this monastery had been reading one of Aristophanes' plays, in which a slave exclaims "Let us force a stake into his mouth as do the cooks, and then, by pulling out his tongue, we will examine, boldly and at our ease, his wide-opened mouth to see if he is measled!'

Following the Renaissance, man became more objective in his thinking: to be guided by instinct and mysticism alone was not enough. Trade flourished, and, with the interchange of goods between countries, followed the interchange of skills, ideas and knowledge. It was an age of vitality when the spirit of adventure led men to create wonderful works of art, to seek distant lands and to search for truth. Thus we find in the ensuing years that life was gradually becoming more and more the beautiful and expansive thing it should be, marred only by Wars and Pestilence. It was the latter which challenged and engaged the curiosity of some of the foremost thinkers of the time, resulting in an investigation and systematic study of the body and its structure and functions. Before long the researches in this field led to the publishing of whole treatises not only on the anatomy and physiology of the body itself but also on the "altered" or disease signs encountered in it.

By the middle of the nineteenth century some startling information had been brought to light about human disease, not the least important being the fact that certain diseases could be transmitted through animals by the consumption of infected meat. This was particularly true of certain parasitic diseases as evidenced by two outbreaks of trichinosis in Germany affecting some 500 people in the years 1863 and 1865, when it was demonstrated that the 149 deaths resulting from these outbreaks were due to the eating of pork infected with trichinae. Even ten years previous to this Kuchenmeister had demonstrated that the larval or cystic form of the human tapeworm Taenia solium was to be found in the muscles of pigs.

Experiences such as these, followed by the world-shaking discoveries of Koch and Pasteur, led people to become increasingly particular about the things they ate. It is not surprising to note, therefore, that by the turn of the twentieth century, the people of certain European countries were becoming more and more concerned over the possibility that the milk and meat they imported from distant lands might be tuberculous or give rise to sickness through other infective agents. Before long they were demanding that the food they purchased be inspected in the country of origin and certified as wholesome.

Canada's position as a food producer must have been a difficult one at this juncture, since she was no doubt largely dependent upon her exports to bring her the machinery and manufactured artticles she so badly needed. Not least to be considered was the fact that the marketing of dressed livestock overseas was a handy means of disposing of her large grain surpluses.

To meet this emergency, legislation known as the Meat and Canned Foods Act was introduced by the Canadian Parliament in 1907 to provide for a uniform system of inspection and control over all packing plants and abattoirs engaging in interprovincial or export trade. Subsequent amendments to this statute have made it possible to enlarge the scope of our system of meat inspection.

The primary purpose of the present system of Government meat inspection in Canada is:

(1) to detect and destroy diseased and otherwise unfit meat
(2) to prevent the use of harmful preservatives or other deleterious substances in the preparation of meat food products
(3) to ensure that meat products are kept clean during the various stages of preparation
(4) to mark sound and wholesome meat "Canada Approved"
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(1) the building to be constructed of steel and concrete, brick and tile, rather than material of an absorbent nature, such as wood
(2) predominance of impervious floors (tile or concrete), inside walls to be of smooth cement finish, or preferably glazed tile
(3) adequate slaughtering facilities
(4) ample and clean operational space
(5) proper lighting and ventilation
(6) an abundant supply of potable hot and cold water under adequate pressure
(7) rust-resisting metal equipment, preferably stainless steel, for handling meats
(8) modern plumbing and proper sewage disposal: floor drains should be at least 4" in diameter, equipped with deep seal traps and vented: discharge lines for paunch contents must be 8", or more, in diameter
(9) pavement, with drainage connection from livestock pens, and outside premises kept free from objectionable conditions
(10) Welfare rooms well located and properly separated: toilet and dressing-room facilities are required for employees of each sex
(11) suitably located and properly equipped Inspector's offices.

It is essential that the plant lay-out be suited to the type of operations to be conducted, since experience has shown that improper planning invariably leads to general disorder and consequent delays in the handling of products—all of which tend to increase contamination hazards.

Since meat decomposes fairly rapidly at room temperatures, artificial refrigeration of a type and capacity adequate to plant needs is regarded as essential equipment. It is desirable, for instance, that rooms in which certain meats are prepared and processed operate under refrigeration or that refrigerated storage rooms be close to where meats are manufactured and handled. It is no less desirable to have departments where inedible products are dealt with completely separated, and as far removed from the scene of food handling as possible.

Plants that meet Dominion Government sanitary requirements, provided the volume of plant output is sufficient to warrant the full-time services of one or more Dominion Government Inspectors, are granted inspection, on condition that they are able, and prepared, to comply with the regulations made under the Meat and Canned Foods Act. Managements must, for example, agree to the full-time supervision of every operation conducted within their establishments, and cooperate to the fullest extent in maintaining a satisfactory system of control over all incoming products, as well as those that are being sent out. On no account may these establishments give outlet or entry to meat food products that have not been inspected and approved by Government Veterinarians.

Following the granting of inspection and prior to the commencement of operations under inspection, an establishment is staffed with the requisite number of government appointed officers who are responsible to the Veterinary Director General of the Department of Agriculture of Canada, under whose direction Meat Inspection Regulations are administered.

At establishments where slaughtering is conducted, the antemortem and postmortem inspection of animals is carried out by fully qualified government veterinarians. The veterinarians stationed in the stock yards are required to see that all injured, diseased or suspected of being diseased animals are segregated and dealt with as the Inspector in Charge may direct. This antemortem inspection is of great value in more than one respect, viz.:

(1) It affords a large measure of protection to packing house employees since certain animal diseases, such as Anthrax, are readily transmissible and, sometimes, fatal to man
(2) It prevents the use of dead or dying animals for food purposes
(3) It can be of considerable assistance in tracing and preventing the spread of animal plagues.

Animals that have passed antemortem inspection are, after entry into the plant, quickly slaughtered and dressed under the supervision of Veterinarians who specialize in postmortem inspections. All parts and organs of every carcass are submitted to rigid postmortem inspection, and those found to be diseased or unwholesome are carefully identified. All meat found to be unfit for human consumption is consigned to the inedible section of the plant where it is rendered, sterilized and denatured in government sealed tanks.

There are several factors which influence an Inspector's judgment during the course of his postmortem examination, viz., the type or character of the disease encountered, its location and the extent to which it occurs. Variations in the distribution of a disease may also play an important part in deciding whether an entire carcass, or only a small portion of it should be condemned. It can be seen, therefore, that competent inspection serves not only to protect the public health but also avoids the destruction or waste of meat that is in reality fit for human consumption.

In the past year, nearly seventy different disease conditions were encountered in the various classes of livestock slaughtered under inspection: the main causes of carcass condemnation were:

(a) Tuberculosis
(b) Pneumonia
(c) Arthritis
(d) Mucoid Degeneration
(e) Septicaemia

Meat carcases that have passed inspection are washed, and quickly removed to rooms under refrigeration. One of the most important features of Government Inspection is to see that meat which has been passed for food purposes, is hygienically handled and kept free from contamination. Thus great emphasis is placed upon the personal cleanliness and health of all employees of establishments; care being taken to see that those suffering from chest, throat and skin ailments are not permitted to handle edible products. The condition of employees' hands is of particular importance.

Another item of importance in connection with the handling of meat is to see that a safe but effective programme of pest control is regularly carried out in each inspected establishment. In this regard the prompt removal of rubbish from the plant premises, the screening of all windows and ceiling vents is strongly emphasized.

Perhaps the greatest progress made in recent years

has been the establishment of standards for foods. Today, sampling for laboratory examination is carried out in inspected establishments to ensure that the moisture, cereal and preservative content of each meat food product is kept within the prescribed limits, as well as to prevent dyes and substances injurious to health from being used. As a further protection to the consumer, no statement or mark that is calculated to deceive may be shown upon any product: hence all labels must be submitted for government approval before use. These, and all other inspection requirements, are also applicable to imported products.

Meat food products that have passed inspection are marked with the Inspection Legend which is a government mark, circular in shape and on which appear the words "Canada Approved," and the official number assigned to the establishment. In the center is shown the authorized pattern of the Crown.

The far-reaching effects of this compulsory system of meat inspection cannot be over-estimated, for the record shows that Canada has not only retained her old European markets, but has succeeded in establishing new ones in many parts of the globe.

Each year, upwards of eight million cattle, sheep, swine and poultry are handled in inspected establishments throughout Canada, by a staff of approximately 450 officers. Despite the fact that Canada has a large rural population, it is estimated that nearly 70% of the meat consumed is inspected and marked "CANADA APPROVED." This, coupled with the fact that Canada's meat export potential can be reckoned at almost a billion pounds, would indicate that a National system of inspection is not an unwise investment on the part of the Federal Government. To the majority of housewives it is a guarantee that the meat they buy is safe to eat; to the farmer, it is an assurance that more ready markets are available at home and abroad for the food animals he raises.

Continuous Manufacture of Jellied Substances at Low Temperatures[a]

GUSTAVE T. REICH[b]

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The food industry is gradually replacing batch processes with continuous operations. Not all batch processes are readily converted to continuous operation and usually the combined experience of the food technologist and the engineer is necessary in order to obtain a well-balanced operation.

The author describes the conversion of the normal batch process for jelly and jam manufacture to successful continuous operation. He considers the advantages of the continuous process to be closer control of time and temperature, which results in less color and flavor destruction and therefore better quality products.

The trend in the food industries is towards an automatic continuous operation. Whether this can be carried out with every process is problematical. In some instances the batch operation is preferable either from capital investment standpoint or simplicity. Other processes should be semi-continuous, while in most instances the continuous process is desirable and practical.

Unfortunately, many manufacturers are led to believe that to convert a batch process into a continuous process requires only the application of good engineering. Far from it. Sometimes a good food technologist has more success than an engineer, as so many factors enter into the design of a continuous process that in order to get a well balanced process we need the combined knowledge of the food technologist and engineer.

In the following, factors influencing the quality of the products will be discussed briefly.

[a] Presented before the Eighth Annual Convention, Philadelphia, Pa., June 8, 1948.

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Factors Influencing Quality

For the manufacture of jam, jellies, marmalade and preserves, fruit or fruit juice, sugar, pectin and acid are required in a well balanced ratio.

When producing preserves, the cooking procedure, type of structure in the fruit, temperature and kind of sugar, i.e., whether it is pure sucrose, dextrose or a combination of both, have an influence upon the character and degree of the fruit texture.

Every manufacturer strives to retain in his product the fresh fruit flavor and color. Therefore, the aim is to reduce the time of cooking to the minimum at the lowest temperature possible. For this reason, vacuum evaporation is preferred, especially for the manufacture of preserves.

Figure 1 shows the time cycle for the production of strawberry preserves when it is produced according to the batch process under reduced pressure. It requires approximately 30 minutes for charging, concentrating and discharging the evaporator. In this instance the syrup is not separated from the fruit and not concentrated separately.

Principle of the Continuous Process

It has been thought in the past that to control accurately the time and temperature and quality of a preserve or jelly product effectively, it was necessary to conduct the operations on a batch basis, which also limits the amount of material subject to spoilage in a given operation.

Such a conception is erroneous in that by suitable manipulation and by the use of suitable apparatus more uniform results may be obtained by continuous opera-

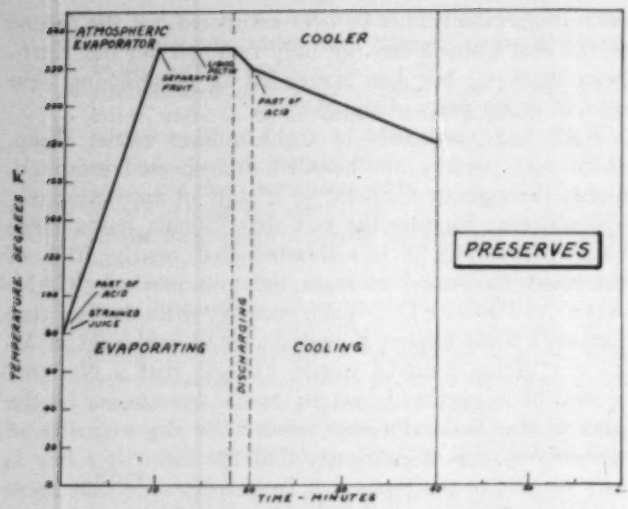

FIG. 1. Time Cycle for the Production of Preserves. Batch Process—Atmospheric Evaporation.

tions. In a properly designged apparatus provision has to be made to insure that substantially every portion of the material is subjected to the optimum time and temperature of treatment. The assumption of uniformity of treatment based on average time and temperature of treatment of a given bulk of material is fallacious. A food product in which one portion has been overtreated and another portion proportionately undertreated and mixed is not equivalent to a product in which each portion has been subjected to the optimum treatment.

In the batch process, all process steps are carried out in jacketed kettles at atmospheric pressure or when vacuum pans are used, a complete charge is moved from the kettle to the pan and then transferred again to another kettle.

In a continuous process it is aimed to carry out preheating, mixing with liquid or granulated sugar and other ingredients and passing forward continuously into a vacuum evaporator, removing continuously the highly concentrated product and then raising the temperature at an even rate for inversion and filling purposes. The apparatus in which all steps are carried out must be very flexible, permitting quick changes from one type of product to another as from jams to jellies or preserves. It must be capable of ready and accurate control of temperature, concentration of liquors, rate of inversion and other factors which must be accurately controlled.

Furthermore, during inversion the albuminoids coagulate and they must be removed as a scum in order to give a clear product. This continuous apparatus should permit the fruit, either whole or crushed, to be mixed uniformly with the jelly base, for example, fruit juice, sugar, pectin and acid, so that no separation or stratification occur in the product.

In the batch process very little power is used, therefore, the power requirements for a continuous process should be relatively low, likewise steam consumption. A continuous apparatus should be capable of producing a large output with a minimum of labor and should conserve floor space and be easily cleaned and maintained in a sanitary condition.

Finally, it should yield a finished product of uniform and controlled quality.

A few years ago the author described a continuous process for the production of 200,000 pounds of cranberry sauce per day at atmospheric pressure *(2, 3)*.

In the following a process and apparatus for the continuous production of jelly, jam, marmalade and preserves will be discussed and thus open a new vista, departing from the traditional batch process *(4)*.

Continuous Vacuum Process

A perusal of the batch process shows that the time factor for each step varies. Charging and preheating, transferring to vacuum pan, cooking, discharging, each step is timed differently. In the continuous process an even, uniform flow of material does take place and it is characteristic of the process that at no stage does the temperature of the liquid exceed the atmospheric boiling point. Operation under such conditions preserves the activity of pectin, consistency of the fruit and conserves essential oils. Figure 2 shows the time cycle for

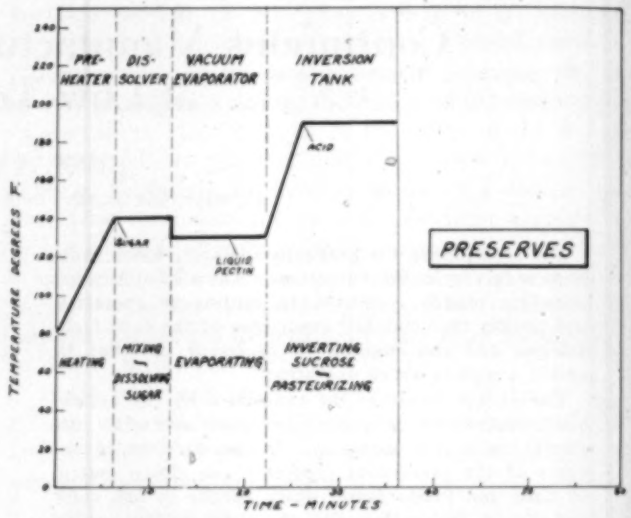

FIG. 2. Time Cycle for Processing Continuously.

the production of preserves according to the continuous process.

The principle of the continuous process is preheating; dissolving sugar or mixing with other materials; evaporating and inverting sugar in separate zones under optimum conditions appropriate to each step.

In order to accomplish the above results the apparatus as shown in Figure 3 consists of four units—preheater, mixer, evaporator and inversion tank. The latter also serves simultaneously as a pasteurizer.

Preheater and Dissolver

This unit serves for receiving the fruit juice, crushed fruit or thawed out frozen fruit, and the temperature raised to between 120° and 140° F. (48.5°-59.5° C.), suitable for subsequent processing. From the preheater the material passes into the dissolver, where granulated or liquid sugar or other materials are added and the temperature maintained in this unit also at 120° to 140° F.

The preheater and dissolver are elongated horizontal

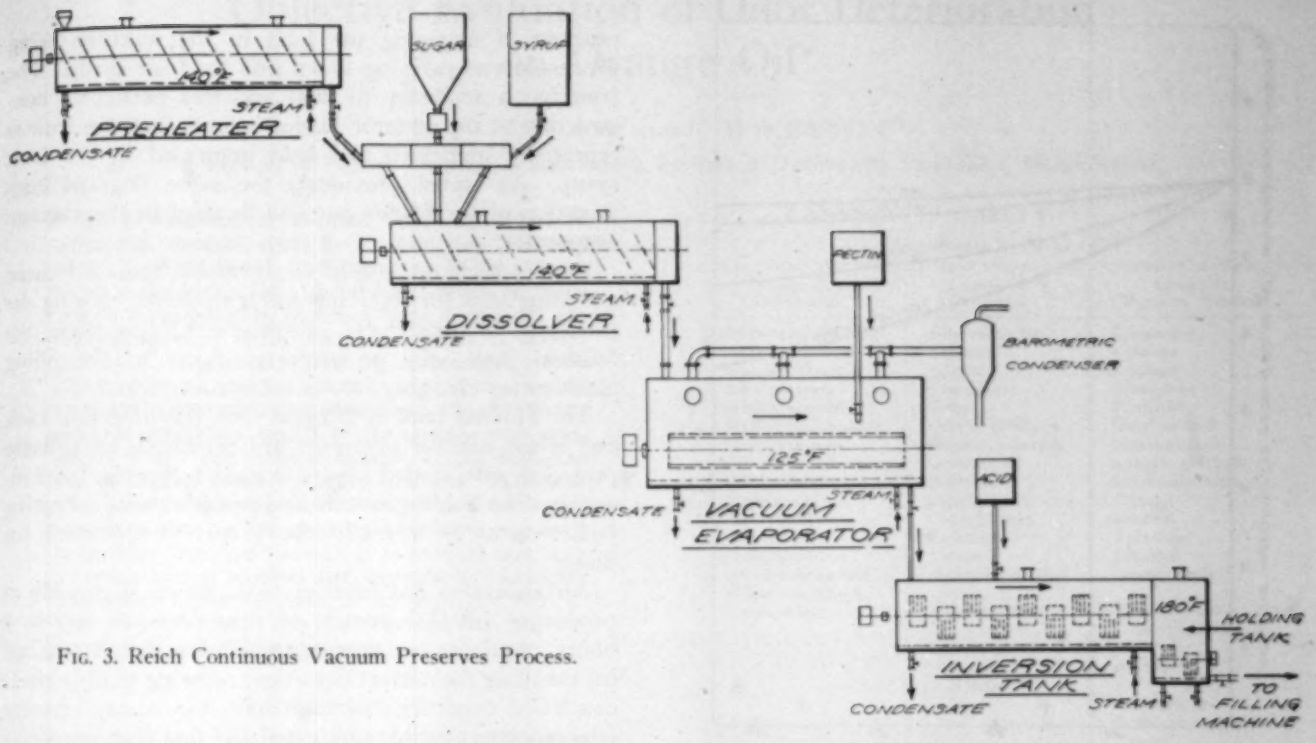

FIG. 3. Reich Continuous Vacuum Preserves Process.

jacketed tanks, each provided with a specially built agitator which serves also as a heating unit. The dissolver differs from the preheater primarily in the construction of the agitator as each unit handles different materials and serves different purposes. They are provided with a removable cover which gives access to the tanks for cleaning and servicing purposes. Provision has also been made for the use of an inert gas so as to exclude the air and prevent the oxidation which would destroy the fruit flavor and impart an off taste to the finished product.

A very important feature of the design of these two units is, that they permit a 50 percent reduction in the production and still the product flow is uniform, i.e., if the time factor through each unit should be 10 minutes, it will be the same whether the production is 100 or 50 percent and whether we handle liquids only or stratified products such as thawed out strawberries or cherries.

The preheater and dissolver are provided with relatively large heating area, thus permitting rapid heating with steam of 20 p. s. i.

The granulated sugar, or liquid sugar is added to the preheated product at a predetermined rate and quantity, so that the final product will have the ratio of fruit and sugar as required by the Government. The design of the agitator is such that the granulated sugar is dissolved very rapidly and caramelization is avoided.

Vacuum Evaporator

The vacuum evaporator is an elongated enclosed tank, provided with a semi-cylindrical bottom and heating jacket. The evaporator is provided with a heated agitator having a hollow shaft section, to which hollow agitator blades are mounted on tubular radially extending arms. The steam flows from the shaft section into the blades through the radial tubes and the condensate from the blades is carried out through the tubes. The blades are longitudinally corrugated to provide increased heating surface and the warped external surface will catch floating pieces of fruit and carry it down into the body of liquid in the tank.

If the evaporator is to be used only for the production of a specific product then we may provide agitator blades as will be described under inversion tank.

In this unit also the ratio of heating surface to tank volume is relatively high which makes it possible to evaporate large amounts of water in a short time without employing deleteriously high temperatures in the heating jacket and agitator.

The vapors from the evaporator are removed through two or more vapor lines and then pass according to the standard practice through a catchall and finally to a barometric condenser or jet ejector.

Owing to the continuous flow the density of the liquid changes continuously, i.e., it increases towards the discharge end. Therefore, very careful control must be maintained and for this purpose the evaporator is provided with several proof sticks which permit the checking of the liquid density at any point of the evaporator.

When the standard vacuum pan is used, the procedure is to concentrate the fruit to a predetermined density and add liquid pectin to it and finish the charge. In the continuous process, liquid pectin can be continuously introduced into the pan at several points. That the vacuum evaporation has less destructive action upon the pectin can be seen in Figure 4, which according to Baker *(1)* at 130°-150° F. (54.5°-65° C.) at pH 4-5, is negligible, but the slope increases as the pH is lowered, about twice at pH 2.5.

The evaporator is provided with several manholes and gas tight covers on both sides, giving access to the interior of the evaporator for cleaning purposes. The level of liquid in the evaporator may be observed and controlled through suitable sight glasses.

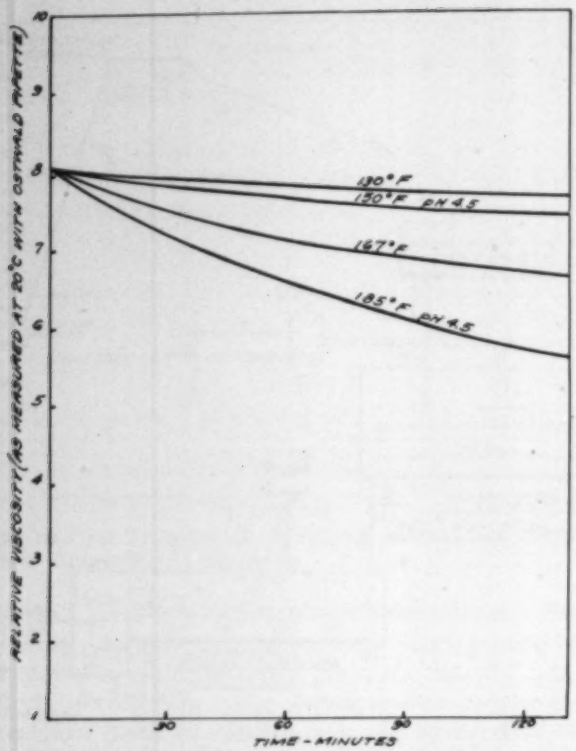

FIG. 4. Degradation of Pectin in Solution (0.5%) with Time of Heating.

If atmospheric evaporation is desired the barometric condenser is by-passed. Likewise, should we desire to recover part of the vapors, a surface condenser can be placed between the evaporator and barometric condenser, which is sometimes used on batch evaporator.

Inversion Tank

The inversion tank consists of two tanks as an integral unit. The inversion tank is an elongated horizontal tank divided into three or more communicating sections by longitudinally extending vertical baffles. These baffles are provided with openings, permitting a continuous flow in a zig-zag direction. The inversion tank has a jacket permitting a rapid heating of the product coming from the evaporator from 125° up to 180° F. (50.5°-82° C.) The raising of the temperature results in the inversion of part of the sucrose, pasteurization and a free flowing product for filling purposes.

The inversion tank is also provided with two types of agitators which can be interchanged readily. When jelly is to be produced the agitation should be such that the albuminoids can separate easily and be collected on the top of the product. If the agitation is too violent, albuminoids will not separate as easily removable scum, but will remain in the jelly and result in an unmarketable product. Therefore, the agitator blades merely move the scum forward *(4)*.

Should we process preserves it is essential to keep the fruit submerged in the liquid and prevent stratification. Therefore, the agitator shaft is provided with curved blades. The inner edge of the blade is affixed to the shaft and is partly solid to give rigidity. The blade is slotted at spaced intervals to provide relatively long thin radially extending fingers and they are slightly curved in the direction of rotation of the agitator for the purpose of engaging the fruit in the mixture being processed and carrying down into the fruit syrup. The fruit has a tendency to float and this particular construction of the agitator blades insures that the fruit is repeatedly immersed and held immersed in the fruit syrup. As stated previously the same fingered construction of the blades can also be used in the vacuum evaporator.

At the discharge end of the inversion tank is located a holding tank for receiving and temporarily storing the processed food products. From the holding tank, the finished jam, jelly or preserves flows to the filling machine for charging into suitable containers.

The holding tank is integral with the inversion tank and when jams or preserves are produced, an agitator provided with slotted blades is used to prevent stratification. The holding tank is also provided with a heating jacket so as to maintain the proper temperature for filling.

An apparatus has been erected, which is capable of producing 120,000 pounds of preserves per day in 8 hours, requiring one operator and one assistant (mainly for checking the correct densities). Owing to the closely controlled conditions on each unit, the human element is as much as possible eliminated and that each necessary function is effected without disturbing or unduly influencing the other functions is one of the cardinal points in the continuous process.

Summary

1) Problems to be considered for the production of a quality product and their influence upon the design of a continuous process.

2) A brief description of a batch process operated at atmospheric or reduced pressure is given.

3) The principle of the Reich process for the manufacture of jam, jellies, marmalades and preserves applying vacuum evaporation is described.

4) Large production with a few operators can be achieved by operating continuously.

5) An apparatus required for the production of jam, jellies, marmalade and preserves consists of a preheater, dissolver, vacuum evaporator and inversion tank.

6) The temperature maintained in the continuous process up to the inversion tank never exceeds 140° F. (58.5° C.).

7) The maximum steam pressure on the preheater and dissolver is 20 p. s. i.

8) The continuous apparatus has great flexibility, permitting the production of jelly or preserves.

9) Unit capable of producing 120,000 lbs. of preserves daily is in actual operation.

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Objective Evaluation of Odor Deterioration in Orange Oil[a]

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The development of so-called "terpeney" odors in citrus oils, brought about by air oxidation, has long been a problem in the food industry. In an attempt to place the evaluation of odor deterioration in citrus oils on a reproducible, objective basis, orange oil (as representative of citrus oils) was studied by several techniques. A standard Warburg manometric system was used to measure the quantity of oxygen absorbed by the oil under controlled conditions. Changes in the infrared absorption spectra of the samples were studied, to follow the chemical changes during oxidation and to suggest possible reaction products. Calibrated odor panels employing the method of paired comparison gave data on the quantity of oxygen necessary to produce "terpeney" odors. It is believed that such a combination of physical and organoleptic techniques may afford a new approach to the important field of odor evaluation, not only for essential oils but for many foods and food components.

Introduction

Orange oil and citrus oils in general are prepared in large quantities by expression or distillation from the oil cells of the fruit rind and are used extensively for flavoring purposes in the manufacture of baked goods, confectionery, beverages, and similar food products. After expression and prior to use, these oils are particularly subject to an odor deterioration. This deterioration results in "off" odors, which are described in the essential oil trade as "terpeney" and are attributed to autoxidation by atmospheric oxygen.

Unfortunately these oils are not simple chemical materials but are, rather, mixtures of several compounds (see Table 1), some of which may be present in only small amounts but have considerable effect on the odor of the mixture. Heretofore, experimenters have studied citrus oil deterioration from the chemical standpoint, and much work has been done in studying the constituents of the oils. The data thus obtained have been admirably summarized in such standard texts as those by Gildemeister and Hoffman *(1)*, Parry *(2)*, and recently by Guenther *(3)*.

The investigation described in this paper was an attempt to approach the problem from a slightly different point of view, with the use of two major techniques:

(1) The use of calibrated odor panels, whose results are analyzed statistically.

(2) The use of the newer physical methods of analysis, such as oxygen absorption techniques and infrared absorption spectroscopy.

It was felt that these techniques, properly employed, might throw new light on citrus oil deterioration, supplementing the information now available by showing that air oxidation is primarily responsible for "terpeney" odors and can be reproduced in the laboratory under accelerated and controlled conditions. In addition, it was hoped that the compounds responsible for the "off" odors could be tentatively identified.

The observations were made on orange oil, as representative of citrus oils in general.

TABLE 1

Constituents of Citrus Oils[a]

Orange Oil (California)	Lemon Oil (California)	Lime Oil (Mexican Distilled)
d-limonene 80-90%	d-limonene 80%	d-limonene
n-capric aldehyde	α-pinene	α-pinene
l-linalool (trace)	β-pinene	β-pinene
d & l-terpineol	γ-terpinene	Bisabolene
n-nonyl alcohol	Citral	Furfural
Methyl anthranilate	Octylic aldehyde	Octyl alcohol
Caprylic esters	Nonylic aldehyde	Nonyl alcohol
Citral	Geraniol	n-capric aldehyde
Citronellal	Acetic acid	Lauric aldehyde
Formic acid	Capric acid	Citral
Acetic acid	Caprylic acid	Borneol
Capric acid	Cadinene	Terpineol
Octyl alcohol	Linalool	Linalool
An olefinic alcohol	A tertiary alcohol	Lauric alcohol
White amorphous compound	An aldehyde	Esters of acetic, octylic, decylic, acids
	An amorphous compound (Citrapene)	An azulene
		An aldehyde
		A phenol or phenol ester

[a] The data in this table are compiled from sources in references 1, 2, 4, and 5.

Odor Panel Tests

The difficulties of making complicated odor tests requiring considerable time and attention on the part of the observer are obvious. Hence it was decided to design these tests to be as simple as possible and still furnish the desired information.

The method of paired comparisons *(6)* was adopted. In this type of test the observer was given two samples at a time, one of which was always a fresh control sample and one of which might be either a similar fresh sample or an oxidized or treated sample. The respondent was asked to judge, from smelling the samples, whether he could detect a difference in the two odors. This procedure was repeated twenty times for each observer, at intervals of thirty minutes or more between the presentations of paired samples. This time interval, plus the fact that only two samples were smelled at a time, was considered sufficient to minimize any effects of fatigue or olfactory adaptation that might be present.

Ordinarily from three to five responses were made by an observer on any one day, which means that the twenty judgments were spaced over a period of several days. This raises the objection that the observer may vary in sensitivity from day to day. It was decided to retain this variable in the experiments, however, for

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, California, July 13, 1949.

[b] Present address: National Research Council, 2101 Constitution Avenue, Washington 25, D. C.

under these conditions detection of odor difference would be of more significance.

The order in which the two members of a pair were presented to the observer was determined by the tossing of a coin and was the same for all observers.

The samples were presented in approximately 5-ml. portions, contained in 25-ml. weighing bottles with ground-glass stoppers. The bottles were coated with black glyptal paint, baked dry, to conceal any color differences that might exist in the samples. The bottles were thus identical in appearance.

In general, the observers were uninformed concerning the nature of the test and the samples, in order to eliminate personal bias as much as possible.

In the calculation of the significance of the results, the observer's score is compared with the theoretical score that would be obtained by chance. The theoretical chance score can be calculated from the binomial expansion: $(\frac{1}{2} + \frac{1}{2})^n$

where n is the number of trials.

The deviation of the observer's score from the theoretical chance score when known "off" samples are used in the paired comparison test is a measure of the observer's acuity to smell. When an observer has been found to have an acute sense of smell and that observer is judging unknown samples, the deviation of his score from the chance score is indicative of an actual difference in the odors of the samples.

The significance of the deviation of the observer's score from the chance score can be readily measured by the Chi Square test *(7, 8)*. A probability level of 0.05 in the result obtained by the Chi Square test was chosen as indicating that the observer's preference deviated significantly from chance. This probability level was chosen arbitrarily, because it is the level generally accepted in biological research *(9)*, and no evidence for the need of a more rigorous criterion was available.

Selection of the Odor Panel

Members of the odor panel were selected ("calibrated") by means of a series of paired comparison tests. In these tests, two oils of known quality obtained from industry were used. One sample was an oil judged by experts of the commercial concerns to be "terpeney" and, therefore, unfit for commercial use. The second was an oil of the same type and from the same source but considered fresh and acceptable. Those individuals who could successfully detect the odor difference in the two oils with a score significantly greater than that obtainable by chance at the 0.05 level of probability were chosen as panel members. Three individuals of a group of fifteen tested showed adequate sensitivity and were used on the panel for subsequent tests.

Oxygen Absorption Technique

The rate of oxygen absorption by a sample of orange oil can be measured by a relatively simple technique that will give reproducible results. Many investigators in the field of edible fats and oils have used this technique for the study of rancidity *(10, 11, 12)*. In this present study the technique was employed to furnish a standard method of oxidizing the orange oil samples under controlled conditions, in which the amount of oxygen taken up by the sample would be known.

A standard Warburg apparatus and the constant volume technique were employed. Such equipment and technique are thoroughly described in standard texts on this subject *(13, 14)*.

The oxidations were carried out at 40° C. with a variation of ± 0.1° C. The reaction flasks were fully immersed in the constant temperature bath and were shaken at a rate of 70 strokes per minute, with a total throw of approximately two inches. Each sample weighed one gram. The amount of oxygen absorbed per gram of oil was calculated from the weight of the sample, the change in pressure of the air in the apparatus as recorded by the manometers, and the dimensions of the system.

Infrared Spectroscopy

The instrument used in this study was the Beckman Infrared Spectrophotometer, Model IR-2. Certain modifications had been made in the instrument, such as that permitting a larger cell to be used, but from the standpoint of operation these changes were unimportant. The instrument was equipped with an automatic pen-and-ink recording device made by the Brown Instrument Co.

The region of the spectrum covered was from approximately 2.2 to 15 microns. Because it has become the custom in the field to report results in terms of the working curves, especially for qualitative and comparative measurements, rather than to recalculate the data in terms of wavelength and frequency, this custom has been followed here. The approximate wavelength regions, however, have been reported, from scales available on the instrument.

Experimental

Samples of orange oil were exposed to atmospheric oxygen at elevated temperatures under the controlled conditions described above, and the amounts of oxygen absorbed over various periods of time were determined.

Figure 1 shows a series of oxygen absorption curves obtained by this method with fresh coldpress California orange oil. These are typical curves for oxygen absorption by orange oil. The point of break in the curve where the uptake greatly increases in rate is slightly different for the several reaction flasks used, because of the slightly different dimensions of the individual flasks and, hence, a difference in the surface areas of the oil exposed.

Samples of oil at definite, increasing time intervals were taken, and infrared absorption curves were made until the spectrum of the orange oil from the Warburg runs was practically identical with that of the "terpeney" orange oil used in the selection of the odor panel. This invariably occurred when the sample had absorbed from 6,000 to 8,000 cu. mm. of oxygen N. T. P. per gram of oil. When this quantity of oxygen has been absorbed, it can be considered likely that normal, fresh orange oil will become practically identical chemically

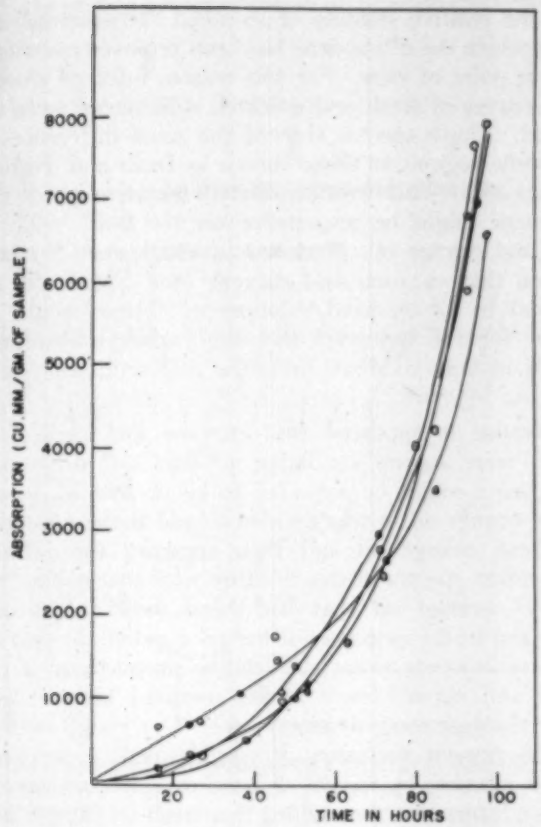

FIG. 1. Curves of oxygen absorption of fresh orange oil exposed to atmospheric oxygen at an elevated temperature (40° C.).

(as evidenced by infrared absorption spectra) with "off" oil.

To determine when a detectable difference in odor occurred in the Warburg oxidized orange oil, paired comparison odor tests were carried out. The pairs consisted of a fresh oil control and a Warburg oxidized sample that had absorbed between 7,000 and 8,000 cu. mm. of oxygen N. T. P. per gram of oil. Table 2

TABLE 2

Paired Comparison Odor Tests on Warburg Oxidized Orange Oil and Fresh Orange Oil

Observer	Number of Trials	Percent Difference Judgments	Significance
1	20	100	Very high
2	20	100	Very high
3	20	100	Very high

shows the results of these tests. Inasmuch as a level of 75% difference judgments in 20 tests is significant (probability of 0.05), the results indicate that a significant difference exists between the odor of the oxidized oil and that of the fresh sample.

Therefore, it is evident that when a sample has absorbed this amount of oxygen, its chemical composition is similar to that of "terpeney" oil, and its odor will be judged by a panel of calibrated observers to be "off" from that of the fresh sample.

As a first step in the identification of the compound or compounds responsible for the "terpeney" odor of oxidized orange oil, infrared absorption spectra were obtained on both the fresh and the "off" orange oil that had previously been used to standardize the odor panel. Figures 2, 3, and 4 show a comparison of these spectra in the regions from 2.2 to 15 microns where significant differences occurred. These regions represent, respectively, the so-called hydroxyl, carbonyl, and phenyl regions and indicate that oxidation results in the formation of these groupings in the constituents of orange oil.

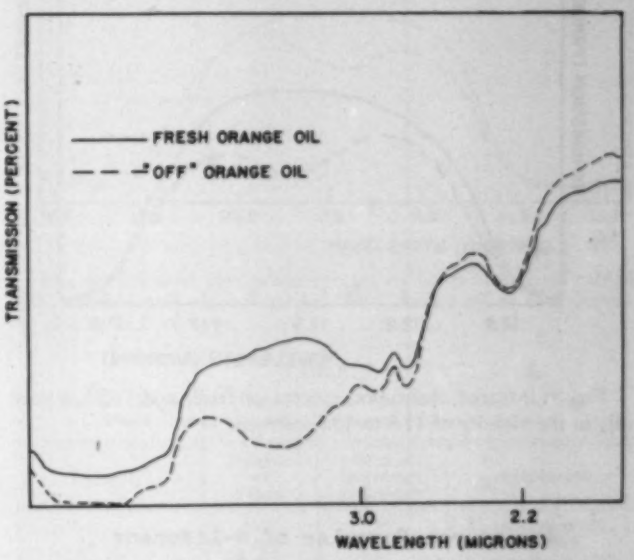

FIG. 2. Infrared absorption spectra of fresh and "off" orange oils in the vicinity of 3.0 microns.

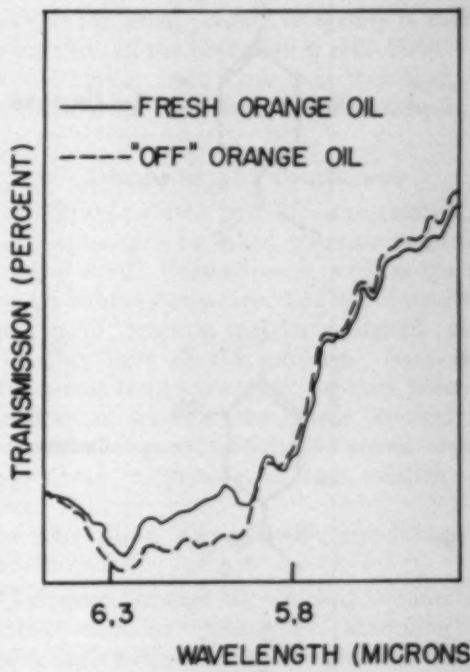

FIG. 3. Infrared absorption spectra of fresh and "off" orange oils in the vicinity of 5.8 to 6.8 microns.

For many years it has been believed by investigators in the field of citrus oils that d-limonene (see Figure 5), when subjected to autoxidation, is responsible for the deterioration in the odor and quality of these oils. The ease with which d-limonene undergoes oxidation, its presence in the oil to the extent of 80 or 90 percent,

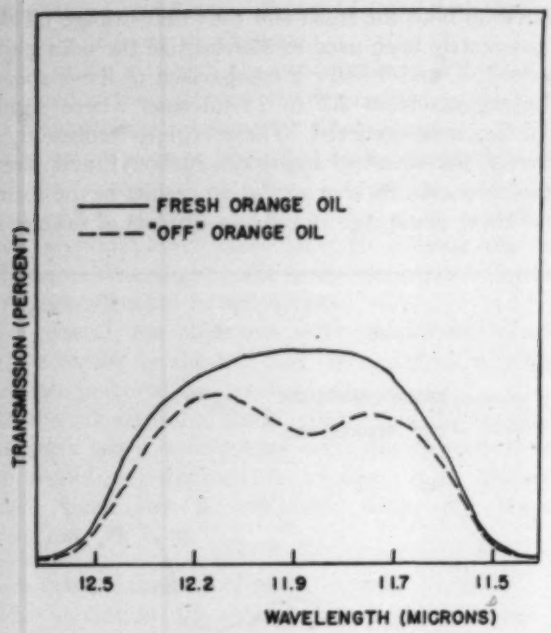

FIG. 4. Infrared absorption spectra of fresh and "off" orange oils in the vicinity of 11.5 to 12.5 microns.

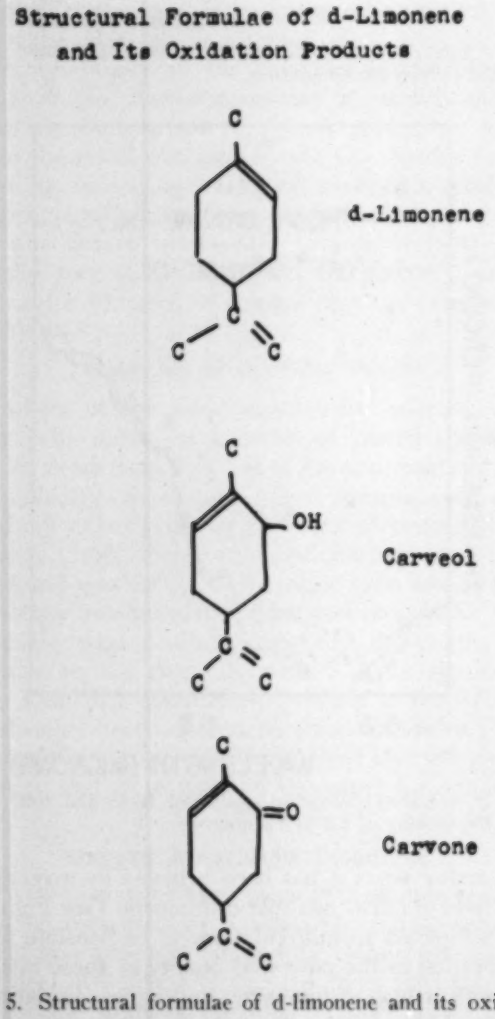

FIG. 5. Structural formulae of d-limonene and its oxidation products.

and the relative stability of so-called "terpeneless" oils from which the d-limonene has been removed contribute to this point of view. For this reason, infrared absorption curves of fresh and oxidized d-limonene were obtained. These spectra showed the same differences in the same regions as those shown by fresh and oxidized orange oils. This was considered tentative proof that limonene might be responsible for the "off" odors of oxidized orange oil. Previous investigators *(15)* have shown that carvone and carveol (see Figure 5) are present in air-oxidized d-limonene. These would account for the hydroxyl and the carbonyl absorption bands in both oxidized limonene and oxidized orange oil.

Because it appeared that carvone and carveol, at least, were logical oxidation products of d-limonene and hence might be expected to be present in autoxidized orange oil, it was decided to add these substances to fresh orange oil and then compare the infrared absorption spectra of this mixture with that of the "terpeney" orange oil that had been used as an odor standard in the selection of the odor panel. It was not known, however, what the relative proportions of carvone and carveol were in the oxidized oil nor what their absolute concentrations were. As a rough estimate of the amount necessary, it was decided to prepare a 50-50 mixture by weight of pure carvone and carveol. This mixture was then added to a fresh oil sample until the refractive index of the mixture was practically equal to that of the "terpeney" sample. An infrared absorption spectrum of the mixture was then obtained.

Figures 6 to 8, inclusive, show a comparison of the only regions of the spectra in which differences occurred between the mixture of fresh oil, carvone, and carveol and the "terpeney" sample. In both Figure 6 (hydroxyl region) and Figure 7 (carbonyl region) the differences are quantitative rather than qualitative, for the hydroxyl and carbonyl bands of both samples show greater absorption than the fresh oil alone. Figure 8 shows that some compound absorbing in the phenyl region is present in the "terpeney" sample which is not present in the fresh oil-carvone-carveol mixture. This would indicate that carvone and carveol are not the only reaction products resulting from the autoxidation of orange oil.

Tentative indications have been obtained that this compound is probably not p-cymene, which would seem a logical possibility. However, the true identity of the substance causing the phenyl absorption has not been determined.

The probable presence of carvone and carveol in oxidized orange oil having been shown, it now became of interest to show whether these compounds were responsible for the "terpeney" odor associated with oxidized orange oil. This was done by submitting to the odor panel paired samples of the fresh oil-carvone-carveol mixture and the "terpeney" sample. Table 3 shows the results of these tests. As can be seen, only one of the observers [c] indicated by his responses that a significant difference existed between the two samples.

[c] A score greater than 75% difference judgments in 20 tests.

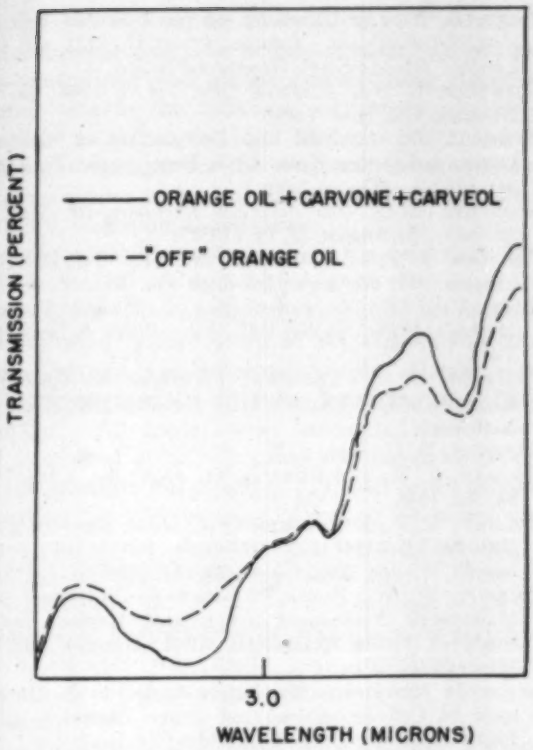

FIG. 6. Infrared absorption spectra of fresh orange oil mixed with carvone and carveol and of "off" orange oil in the vicinity of 3.0 microns.

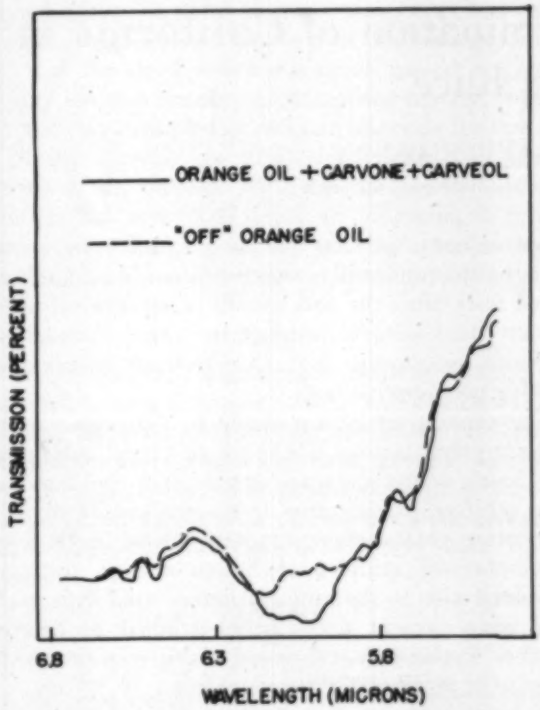

FIG. 7. Infrared absorption spectra of fresh orange oil mixed with carvone and carveol and of "off" orange oil in the vicinity of 5.8 to 6.8 microns.

This particular observer happened to be especially sensitive to the "terpeney" odor and in many tests scored consistently high, usually in the neighborhood of 90% difference judgments or better. As can be seen, his score in this case is well below his usual 90%. Furthermore, if the usual pooling of results is carried out, the average for all the observers is only 70%.

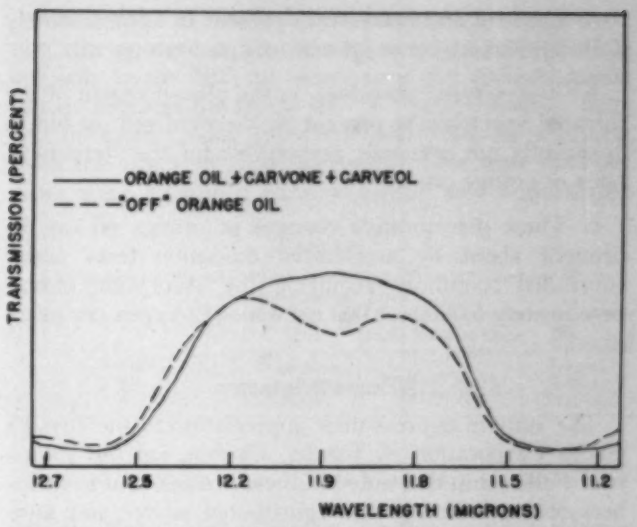

FIG. 8. Infrared absorption spectra of fresh orange oil mixed with carvone and carveol and of "off" orange oil in the vicinity of 11.2 to 12.7 microns.

TABLE 3

Paired Comparison Odor Tests on Terpeney Orange Oil and Fresh Orange Oil with Carvone and Carveol Added

Observer	Number of Trials	Percent Difference Judgments	Significance
1	20	55	No significant diff.
2	20	85	Significant diff.
3	20	70	No significant diff.

Avg. % Diff. Judgments = 70.

It would appear from these data then that, if a difference existed in the odors of these samples, it was slight.

Discussion and Conclusions

As can be appreciated from this presentation, the results obtained cannot be called quantitative in the strict sense of the word. Further work, such as the isolation of pure crystalline derivatives and the quantitative determination of reaction products should eventually throw further light on this problem. However, aside from the actual results obtained, the data illustrate how combinations of some of the newer physical methods and properly designed, statistically sound organoleptic techniques can contribute to the solution of odor problems.

From this study, the following conclusions can be drawn:

1. "Terpeney" orange oil, which is commercially unacceptable, contains substances absorbing in the hydroxyl, carbonyl, and phenyl regions of the infrared spectrum.

2. The absorption in the hydroxyl and the carbonyl regions is probably due mainly to carvone and carveol, which are reaction products from the air oxidation of d-limonene.

3. The presence of carvone and carveol in deteriorated orange oil is responsible for the so-called "terpeney" odor.

4. Carvone and carveol are present in approximately a 50-50 mixture by weight in oxidized orange oil.

5. A compound absorbing in the phenyl region of the infrared spectrum is present in the oxidized oil but is apparently not primarily responsible for the "terpeney" odor of orange oil.

6. These deteriorative changes in orange oil can be brought about by accelerated oxidation tests under controlled conditions requiring the absorption of approximately 6,000 to 8,000 cu. mm. of oxygen per gram of oil.

Acknowledgments

The authors express their appreciation to the Bruce's Juices Corporation of Tampa, Florida, for the Industrial Fellowship that aided in these studies, and to members of the industry who contributed advice and samples. Thanks are due especially to Dr. Richard C. Lord and his colleagues of the Spectroscopy Laboratories at the Massachusetts Institute of Technology for their aid, encouragement, and advice in the infrared absorption phases of this investigation.

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Certain Inaccuracies in the Determination of Coliforms in Frozen Orange Juice[a]

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No coliform organisms were isolated from 62 samples of commercially packed orange juice. Lactose fermenting yeasts occurring in orange juice cause false positive results with standard lactose broth and in large inocula, with brilliant green lactose bile and lauryl sulfate tryptose broths. Colonies of some of these yeasts bear a very close similarity to colonies of Escherichia coli when transferred to eosin methylene blue agar.

Wolford and Berry *(4, 5)* have reviewed much of the literature relating to the bacteriology of citrus juice. These authors showed the presence of *Aerobacter* and coliform intermediates in slime from a citrus processing plant. Such a condition conceivably might result in a significant number of these organisms in citrus juice. Their studies on the effect of storage of frozen citrus juice at —17.8° C. demonstrated a decrease in total count, yeasts, molds and coliforms. Although there was no consistent decrease in the number of positive presumptive tests between one month and seven months' storage, the uniformly negative confirmed and completed tests after the first month of storage of coliform contaminated samples indicate the rapid elimination of coliforms on storage and the spurious nature of the positive presumptive tests.

The present study was made to determine whether brilliant-green lactose bile broth or lauryl sulfate tryptose broth would decrease appreciably the number of false positive presumptive tests obtained from lactose fermenting yeasts when standard lactose broth is used. A number of samples of frozen orange juice were examined also to determine whether coliforms of fecal type were present and further studied to determine whether *Escherichia coli* would multiply in orange juice at room or refrigerator temperatures.

Materials and Methods

Sixty-two samples of frozen unpasteurized orange juice were examined for total number of bacteria, yeast, molds and for coliforms. The samples were examined in groups of eight by allowing the contents of the cans to melt in running cold water after which they were shaken vigorously, opened aseptically and 3 30.0 ml. samples removed from each. The remainder of certain

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, California, July 12, 1949.

[b] The samples of frozen citrus juice for these experiments were furnished to the authors through the kindness of R. M. Hagen of the California Consumers Corporation and W. E. Baier and J. W. Stevens of the California Fruit Growers Exchange.

samples was utilized for inoculation with pure cultures of *Escherichia coli*. The acidity of each 30.0 ml. sample was neutralized with sterile NaOH using sterile brom thymol blue as the indicator. Tryptone glucose agar was used to obtain the total bacterial count and Saboraud's glucose agar for the yeast and mold counts. The dilutions plated were equivalent to 0.1 ml., 0.01 ml. and 0.001 ml. of the undiluted juice.

In the qualitative examination for coliforms, inocula of 10.0 ml., 1.0 ml. and 0.1 ml. were placed in brilliant green lactose bile broth, lauryl sulfate tryptose broth and standard lactose broth in the Graves modification of the Durham type fermentation tube. Double strength media were used in all tubes receiving the 10.0 ml. inoculum. All media were inoculated simultaneously and incubated at 37° C. using the standard procedure for the examination of water *(1)*. All broth tubes were examined for the presence of gas at 24 hours and 48 hours and those showing gas in any amount were streaked on eosin methylene blue agar. These plates were incubated at 37° C. for a minimum of 24 hours. Microscopic examination of organisms from representative colonies was made and organisms from the colonies were reinoculated into the three lactose broth media.

Preliminary tests to determine whether *Escherichia coli* would multiply in orange juice were made by inoculating known concentrations of a pure culture of these organisms into three sets of five replicate samples of orange juice at pH 4.45. One series was maintained at room temperature, another in the refrigerator at 7° C. and the third series was quick frozen in glycerol and dry ice and maintained at approximately —15° C. The juice was sampled at 24 hour intervals for five days by plating directly on Eosin methylene blue agar to determine the number of *Escherichia coli* surviving. Each plating was made from an independent tube so freezing and thawing would not be a factor in the experiment. These experiments were replicated on 11 different occasions.

Results

The total count of all samples of frozen orange juice examined in this laboratory using Saboraud's dextrose agar and tryptone glucose agar are shown in Table 1. The samples are divided into three groups. Groups 1, 2 and 3, respectively, show counts obtained within one, two and three weeks after receipt from the processing plant. A gradual decrease of numbers with time is evident.

TABLE 1

Counts

		Organisms per cc.		
		Highest Count	Mean Count	Lowest Count
Group I	1	16,000	10,000	6,000
	2	24,000	11,000	6,000
Group II	1	11,000	7,000	5,000
	2	9,000	8,000	5,000
Group III	1	7,000	5,500	3,000
	2	5,000	3,000	2,000

1—Saboraud's. 2—glucose tryptone.

The results of Table 2 demonstrate that gas formation was positive in all tubes of standard lactose broth but only in the 10.0 ml. amounts in the brilliant green lactose bile and the lauryl sulfate tryptose media. Several different colony types were obtained on streaking from the tubes to eosin methylene blue agar, and all types were examined microscopically and reinoculated into the three types of media. Certain atypical colonies were noted which proved to be formed by Gram-negative, non-spore forming short rods which on subculture into lactose broth failed to produce acid and gas. Therefore, all 62 samples were uniformly free of coliform types.

TABLE 2

Numbers of Positive Presumptive Tests from 62 Samples of Frozen Orange Juice

Sample ml.	Media Used in Tests		
	Standard Lactose Broth	Brilliant Green Lactose Bile	Lauryl Sulfate Tryptose
10.0	62	55	54
1.0	62	0	3
0.1	62	0	0

Inoculations of known numbers of *Escherichia coli* were made into orange juice to study the survival and possible multiplication at three different temperatures. An apparent increase in numbers of coliforms at room temperature was noted when colonies apparently typical for *Escherichia coli* were counted, i.e., round slightly raised colonies with dark, almost black, centers showing a greenish metallic sheen when viewed by reflected light. Microscopic examination of the colonies demonstrated that only a minor portion were formed by *Eschericha coli;* the greater number were produced by lactose fermenting yeasts. The yeasts will produce gas when inoculated into lactose broth but will not produce gas in the other two media. These results demonstrated that no reliability could be placed on platings made directly into eosin methylene blue agar. The results summarized in Table 3, for this reason, do not show numbers of microorganisms present but only positive or negative results as to whether *Escherichia coli* survived. In order to secure these results, it was necessary to examine the typical colonies on each plate until those formed by Gram-negative rods were discovered. These were inoculated into the three lactose media in which they would uniformly produce gas. The orange juice samples maintained at room temperature were so over-

TABLE 3

Survival Time of Escherichia coli in orange juice
(Summary of 11 samples pH 4.45)

E. coli/ml.	Days of Storage														
	Room temperature					Refrigerator (7° C.)					Frozen (—15° C.)				
	1	2	3	4	4	1	2	3	4	5	1	2	3	4	5
300,000	+	+	+	o.g.	o.g.	+	+	+	+	+	3 of 11 +				
30,000	+	+	+	o.g.	o.g.	+	+	+	+	+	—	—	—	—	—
300	+	+	+	o.g.	o.g.	+	+	+	+	+	—	—	—	—	—
3	*	—	—	o.g.	o.g.	+	+	+	—	—	—	—	—	—	—

o. g.—overgrown.
*Thirty-seven "typical" coliform colonies on E. M. B. agar were produced by lactose fermenting yeasts.

grown by yeasts and molds after 72 hours that no further determinations could be made. *Escherichia coli* could be recovered from the samples kept in the refrigerator at the end of five days in all cases except where the original inoculum was three organisms per milliliter. Only three of eleven samples that were quick frozen had viable coliforms at the end of five days and these were only present in the samples inoculated with 300,000 organisms per milliliter.

Discussion

A gradual decrease in numbers of microorganisms took place during storage at the laboratory at —15° C. This is in agreement with the results of other investigators working on similar problems.

From previously published results the authors expected to find an appreciable number of the 62 samples of frozen orange juice examined yielding completed coliform tests in the 10.0 ml. and 1.0 ml. aliquots. The results clearly indicate that no coliform organisms were present in the frozen juice although if the results of the false-positive presumptive or confirmed tests only had been considered all samples would have been labelled positive. The next most striking point was the futility of using eosin methylene blue plates for a confirmed test when lactose fermenting yeasts exist that can give colonies identical in appearance to *Escherichia coli* on this medium. It seems rather important that a survey be made to determine whether these yeasts are present in other citrus juices than orange juice and whether they are found in different sections of the country. If they are widely distributed then the presumptive test for determining coliforms in citrus juice should be made using brilliant-green lactose broth media. While this medium has not been effective in preventing gas formation by yeasts when 10.0 ml. inocula were used it has apparently been successful in eliminating the particular species which has given results identical with *Escherichia coli* on the eosin methylene blue agar.

These false positive presumptive tests may originate in some cases because the orange juice introduced into the fermentation tube contains sucrose and dextrose which can be fermented with the production of acid and gas by many organisms beside the coliform group. The fact that brilliant green lactose bile and lauryl sulfate tryptose broths lose their selectivity when large amounts of orange juice are introduced into these media but retain their selectivity when smaller amounts of orange juice are used or when organisms from the plates are reinoculated into these media in which they originally grew indicate that they must be used with caution. In the 62 samples of frozen orange juice examined the false positive presumptive tests developed in part from lactose fermenting yeasts which were present in every sample.

The atypical colonies present on eosin methylene blue agar proved to be other yeasts which did not ferment lactose, lactobacilli and Gram-negative, non-spore forming short rods which did not ferment lactose with the production of acid and gas. The latter may possibly be species of *Erwinia* of which only 6 of the 22 species produce acid and gas in lactose broth. Certain of these organisms might be expected in oranges used for juice since the gas producing strains are all included in the causative agents of soft rots.

The fact that *Escherichia coli* inoculated into orange juice remained viable longer at room and refrigerator temperatures than in quick-frozen juice probably may be explained by the short holding period used in this experiment. Schrader and Johnson *(3)* demonstrated that the death rate of *Escherichia coli* in orange juice is most rapid at 37° C., slower at 25° C. and slowest at —12° C. These latter results are more in agreement with the results obtained with other survival experiments in fruits and fruit juices. Owing to the apparently typical *Escherichia coli* type colonies produced by the lactose fermenting yeasts in these experiments it was impossible to secure a quantitative count. It will be necessary to extend the holding periods in these experiments before a definite answer can be given. The results, however, are not inconsistent with those obtained by Bundesen *(2)* who has found the "coliform" group present in 57 samples of unfrozen citrus juice collected in Chicago but not in samples of frozen citrus juice.

Summary

Brilliant green lactose bile and lauryl sulfate tryptose broths will not prevent false positive presumptive tests when large amounts of orange juice are used as inoculum. Certain lactose-fermenting yeasts are present in frozen orange juice which give colonies identical in appearance to those of *Escherichia coli* on eosin methylene blue agar. No members of the coliform group were found in 62 samples of commercially packed frozen orange juice.

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Some Fundamental Considerations in the Processing of Frozen Orange Juice Concentrate[a]

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Factors affecting the flavor of frozen concentrated orange juice were studied using a taste panel with above-average discrimination and ability to duplicate results.

Among the variables included in tests were source and maturity of fruit, also juice extraction, deaeration, pasteurization, handling, concentrating, blending, packing and freezing, as well as the effect of total count, oil and time of storage. Observations are summarized in figures.

Introduction

Frozen orange juice concentrate is the most spectacular news item in the food business today. An item completely unknown commercially in 1944, the total pack in 1946 has been estimated at less than one million 6-ounce cans. In 1949 the total pack will exceed 200 million 6-ounce units and will consume 14% of all juice oranges raised in Florida, plus an additional quantity from California.

In 1950 it is expected to outsell the old established leaders, frozen peas and frozen strawberries.

Claims to paternity of the new item are being advanced by several companies. It is interesting to point out, with no reference to any particular claim, that work in the General Foods Central Laboratories had advanced to such a stage that on January 12, 1944, a project was initiated bearing the title "Concentration, Freezing and Cold Storage of Orange Juice for Freezing Cabinet Distribution"—a rather prophetic title in the light of present developments.

In the season 1946-1947, a traveling pilot orange juice plant, with a daily capacity of 12,000 cans, was designed and installed at Highland City, Florida. At the season's end it was loaded on a railroad car, shipped to Hollywood, California, and reassembled for the duration of the California season. This unit is now operating on its fifth season in three years: 3 seasons in Florida, 2 in California.

The exploratory projects previously referred to had established the laboratory objective: an orange juice concentrate to be stored at commercial frozen food storage and distribution temperatures and with a high enough initial quality and sufficiently good storage characteristics to bear our brand name. In this paper the authors wish to present:

(1) The work that preceded and culminated in pilot plant design, and
(2) The work now going on as a result of pilot plant and commercial observations over two years.

Plan of Attack

The prime objective of the study was to find out which of the basic processes developed theoretically from earlier explorations would produce an orange concentrate that upon reconstitution would yield the best tasting orange juice. Initially, four fundamentally different laboratory methods were considered as possible starting points for this experimental approach.

Shortly after the initiation of the program, it became apparent that frozen concentrates underwent flavor changes during storage. Since it was assumed samples prepared by the four laboratory processing methods would not change at the same rate or in the same direction, it was planned to reevaluate the methods against each other at regular storage intervals. For purposes of comparison, unprocessed, reamed, single strength juice was also packed frozen with each series, thereby enlarging the basic series to five.

Aside from the two major objectives—(1) appraisal of processing methods on freshly prepared samples, and (2) appraisal of samples stored for various lengths of time, many other studies were simultaneously conducted. These included possible raw material variables, such as source of oranges, size, Brix/Acid ratio, maturity, percent soluble solids, pH, and also a study of modifications of the basic processing methods. A third series of experiments was also started in which an attempt was made to prevent or delay flavor changes during storage.

In order to take into consideration the changes in raw material throughout the season, shipment of oranges was processed every week representative of grove-ripened fruit, picked and washed shortly before being sent to our laboratories at Hoboken. The four basic processing methods, in addition to various modifications, were run on each shipment of Florida fruit as well as each shipment of California fruit. By obtaining representative values of Vitamin C content, citric acid, soluble solids, yield of juice, and flavor score on each fruit shipment, it was possible to keep a running record of the fresh juice characteristics throughout the entire Florida and California Valencia season. Data accumulated were recorded for later study in conjunction with basic processing data.

As soon as the processing of a shipment was completed, the four methods were taste-tested against a freshly burred and screened juice sample from the same shipment. These taste tests were repeated at two month intervals on products of the four basic methods, together with a sample of single strength juice extracted from the same shipment of oranges, vacuum canned, frozen, and stored under the same conditions and for the same length of time as the corresponding processed samples. Records of the bacteriological picture prior to and during processing as well as on storage of the respective shipment were also completed. A total of 15 shipments of Florida Valencia oranges, followed by 13 shipments of California Valencia oranges, covering the periods January to June for Florida and June to Octo-

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, California, July 13, 1949.

ber for California, were processed. The early shipments ranged from 2 to 5 crates per week. These were gradually increased to allow the modifications to an average 20 crates per week.

Description of Basic Processes

The basic methods used in the experimental study were as follows:

Method A—Flash Evaporation—Aroma Recovery Process

Juice was prepared by squeezing oranges in Universal juicer, straining through 10 and 35 mesh stainless steel strainers to remove pulp and seeds, and then concentrated to 48° Brix by use of a flash evaporation apparatus in which the juice was permitted to flow over a very slightly inclined surface heated by a steam chest. Evaporation to 4-fold strength was a matter of seconds only. Fresh juice feed rate was 220 milliliters per second and steam pressure in the chest was approximately 65 pounds per square inch. The evaporating sheet was equipped with a hood wherein the first 10 to 25 percent of condensate containing most of the aromatic fractions could be recondensed. After the run was completed, these aromatic fractions were returned to the 48° Brix concentrate to bring concentration down to 40° Brix. The product was then packed into cans under vacuum and frozen.

Method B—Pasteurize—Concentrate Process

Juice was prepared by squeezing oranges in Universal juicer, straining through 10 and 35 mesh strainers to remove pulp and seeds, and then deaerating by placing in a glass evaporator and subjecting the juice to a vacuum. After deaeration, the material was pasteurized in a special laboratory unit which required a total of 6 seconds to heat the juice to 190° F. (88° C.) at a feed rate of 900 milliliters per minute and cooled to 80° F. (27° C.) in 6 seconds. After pasteurization the product was concentrated under vacuum at 85° F. (30° C.) to 55° Brix. Evaporation rate was 60 milliliters of water per minute and concentration time varied from 60 to 90 minutes, depending on the volume of the original charge. The 55° Brix concentrate was then blended back to 40° Brix with freshly pasteurized juice, packed into cans under vacuum and frozen.

Method C—Freeze Concentration Process

Juice was extracted by reaming on a Sunkist high speed extractor, screened through 10 and 35 mesh screen, and deaerated in a vacuum-pot deaerator. The product was then placed in stainless steel beakers and frozen rapidly by immersion of the container in refrigerated brine. The slush-frozen juice was broken up with a spatula and the ice-concentrate mixture centrifuged in the Tolhurst stainless steel perforate basket centrifuge. The 4-fold concentrate thus produced was vacuum-packed in tin cans, and frozen. No cutback juice was added in this process.

Method D—Florida Citrus Commission Process

Juice was prepared by squeezing oranges in a Universal juicer, straining through 10 and 35 mesh strainers to remove pulp and seeds, and then concentrated under vacuum at 85° F. (30° C.) to 55° Brix. Evaporation rate was 60 milliliters of water per minute and concentration time averaged 75 minutes. The 55° Brix concentrate was then blended back to 40° Brix with raw (unpasteurized) juice. The entire 40° concentrate was packed into cans under vacuum, and frozen. This process is essentially that suggested by the Florida Citrus Commission and developed experimentally in their laboratory at the experiment station then in Winter Haven, Florida.

Method E—Single Strength Frozen Juice (Control)

Juice was extracted by reaming oranges on a slow-speed Hobart reamer, and straining through 10 and 35 mesh screen to remove pulp and seeds. The product was then deaerated under vacuum in the glass laboratory evaporator until foaming ceased. The deaerated juice was then vacuum-packed and frozen. No heat was applied at any time.

* * *

As the work progressed it was found necessary to make minor changes in the various processes, but these have little significance here. Eventually, a very complex program developed. The more important results derived therefrom will be reported here.

Evaluation of Samples by Taste Panels

One, if not the most difficult phase, of this type of research is the assay of flavor quality and change in some quantitative, and if possible, objective terms. In General Foods we use many different techniques of varying degrees of reliability for product evaluation and consumer acceptance; namely, bench test, expert panel test, store test, consumer test, and market test. Due to the limitations and number of samples, materials available and time involved, research on the fundamental characteristics of orange juice has been guided primarily by expert panel evaluation.

The selection of judges for an expert panel is made on the basis of screening tests. Since this kind of panel is primarily for discerning differences rather than measuring consumer acceptance, the screening was based on a series of tests in which three samples were presented in duplicate and the judges asked to match the duplicates. This test is recognized as a measure of the individual's ability to discriminate between samples and to discern differences. Table 1 shows the probability of matching duplicate samples by chance alone.

TABLE 1

Taste Testing Statistics

	Possibility of Matching By Chance Alone in 15 Trials	Corrected Weighting Factor [b]
Matching 3 Pairs	1 Chance in 15	8.0
Matching 1 Pair	6 Chances in 15	1.3
Matching 0 Pairs	8 Chances in 15	1.0

[b] In utilizing these weighting factors for statistical calculations of panel performance, corrections had to be applied to allow for the unequal difficulty of the tests.

The results of the judges were weighed to take into consideration the probability of chance matchings. Fig. 1 shows the rank of 26 individuals in the first screening.

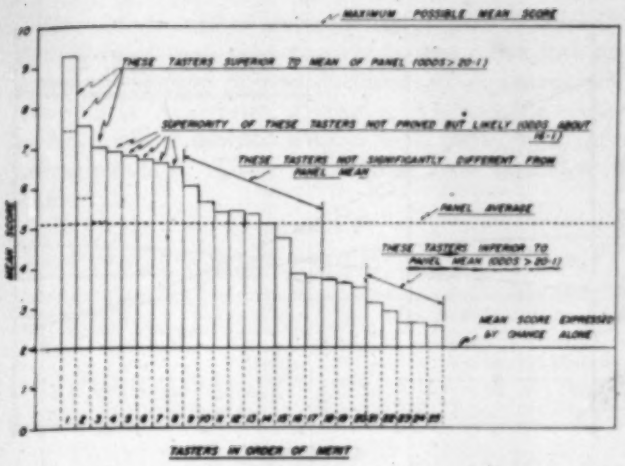
MAXIMUM POSSIBLE MEAN SCORE
THESE TASTERS SUPERIOR TO MEAN OF PANEL (ODDS > 20-1)
SUPERIORITY OF THESE TASTERS NOT PROVED BUT LIKELY (ODDS ABOUT 10-1)
THESE TASTERS NOT SIGNIFICANTLY DIFFERENT FROM PANEL MEAN
PANEL AVERAGE
THESE TASTERS INFERIOR TO PANEL MEAN (ODDS > 20-1)
MEAN SCORE EXPRESSED BY CHANCE ALONE
MEAN SCORE
TASTERS IN ORDER OF MERIT

FIG. 1. Screening test for average juice taste test panel.

The important observation here is that individuals vary widely in their ability to discern differences as well as in their taste preferences!

The results and values of such an expert panel should be treated as relative rather than absolute. For best results, one should always have a point of reference in the series and keep in mind the fact that the environment (i.e., the other samples in the test) has a marked influence in absolute impressions, remarks and quality scores.

A jury of 10 to 14 persons was used on the Taste Test panel for the frozen orange concentrate program. This panel met three times daily. Each tester filled out separate ballots and evaluated for flavor and general acceptability. Comments were required. After each test the ballots were collected and a summary written which gave total score, mean score, and number of firsts. Also, the comments on each ballot were examined and a general summary, including particular remarks about the samples and the tests, made on the summary sheet. Much of the information for this report was obtained from these summary sheets.

According to this scheme of Taste Test scheduling, samples prepared from each particular fruit lot were compared immediately after preparation, with a fresh juice control and at two-month intervals thereafter.

All samples for taste tests were prepared in the laboratory 30 minutes before the test and served to the panel in the test kitchen. The frozen concentrates were removed from storage two hours before the test and allowed to thaw at room temperatures. Concentrates were reconstituted with spring water, aerated and served at a fresh juice temperature of 72° F. (22° C.), with not more than one degree temperature difference among samples. Five samples were usually submitted to the panel to be tasted blind. These included a set of duplicates in about two out of every three taste tests. The insertion of duplicate samples was made to test on the tasting ability of the taster for that particular day. Also, it made it possible to collect statistical records for the purposes of maintaining an accurate panel. In summarizing the total scores for a particular test, all tasters who failed to match duplicate samples within 1.5 points were eliminated and their scores not included in the totals. Each average value established represented 5 to 19 taste tests.

All taste test values used in this record are values assigned to indicate degree of excellence according to a scale beginning with excellent at 10 points, then good, fair, poor, very poor, etc., to zero points.

As a further check on the laboratory panel, duplicate samples were submitted to the Bireley laboratory (Bireley's Division, General Foods Corporation, Hollywood, California). A similar panel, using the same technique, was drawn from Bireley's executives, laboratory and plant personnel, where each test was repeated in an entirely different atmosphere to that prevailing in the Hoboken laboratory. Results of the separate test groups were so close as to require little or no discussion in this report.

Experimental Observations

A. *Effect of Process on Initial Quality and Storage Characteristics*

Taste test evaluations on the five basic methods are available through 12 months' storage. These data have been plotted and are shown in Fig. 2.

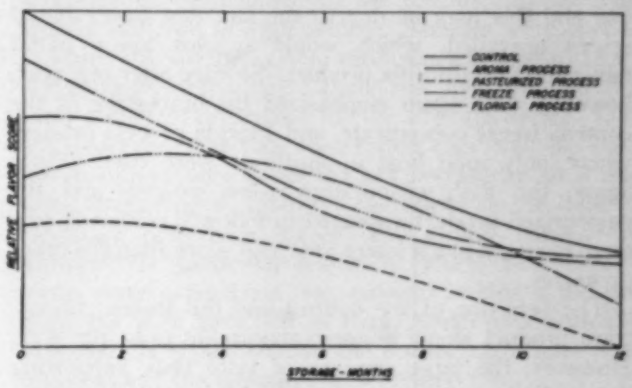

FIG. 2. Taste test results showing effect of process on initial flavor and storage characteristics of frozen orange juice concentrate using Florida Valencias.

It is significant that the freeze concentration method most nearly approaches the control on freshly prepared samples and that initial quality drops off in direct relation to the amount of heat to which the product is exposed during processing After 12 months, the processes having had no treatment or only a very mild heat treatment have come together at about the same level as the fresh juice and have also leveled off in terms of flavor deterioration on storage. The more extensively heat treated samples still fall below this group in terms of average score after storage. It would appear that pasteurization of the concentrate and the cutback juice is readily apparent, both in initial quality and storage characteristics. The early increase in flavor score for the flash evaporation-aroma process is significant since it was observed that this particular product, when fresh, appeared to be unbalanced in relation to various aromatic components.

A similar presentation of the experiments on California fruit is presented in Fig. 3.

In the case of California fruit, initial samples, with the exception of the single strength control, appear to

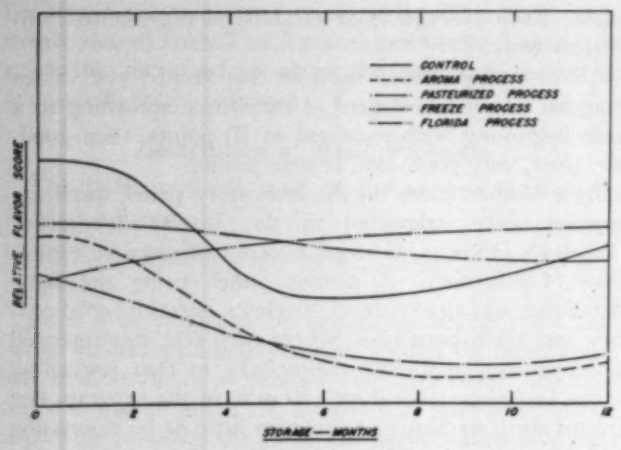

FIG. 3. Taste test results showing effect of process on initial flavor and storage characteristics of frozen orange juice concentrate made from California Valencia oranges.

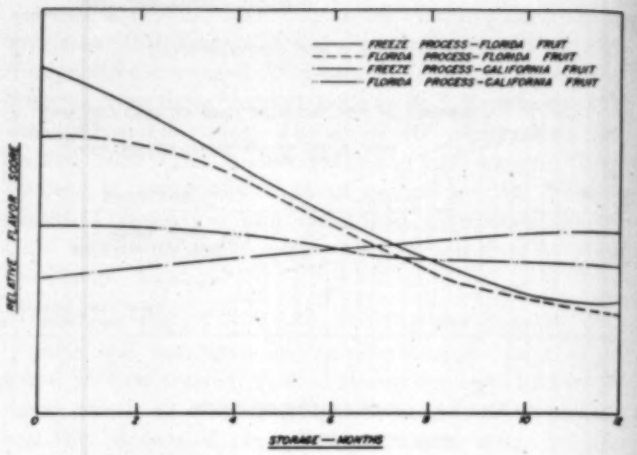

FIG. 4. Comparison of the initial flavor scores and storage characteristics of Florida and California Valencia oranges.

be more closely grouped than was true with the products made from Florida fruit. Both the initial score and the storage behavior patterns seem to indicate a real difference between the California product and that from Florida. Heat effects appear to be much less serious and this may be due to the fact that lower initial scores prevailed, which would suggest lower initial flavor in the California product. Storage after one year, however, once again emphasized the bracketing of the control, freeze concentrate, and Florida process product where only mild heat applications were used. Once again, the flash evaporation-aroma process and the pasteurized product appeared to follow the Florida pattern, having a much lower year-end score than the other processes.

The behavior of the control and the frozen concentrate product would suggest abnormalities in the data. However, the large number of taste tests supporting these observations made it improbable that the points were erroneous. A study of the comments by the taste panels emphasizes the fact that a high quality freshly prepared California juice appears to have a "green or grassy" characteristic, which is unpleasant to many people. It is also less likely to be as well balanced in terms of aroma, sugar and acid as the Florida product. All of these characteristics appear to level off during storage, producing a softening effect on the flavor which evidences itself in a less objectionable score by the taste panel.

For direct comparative purposes between California and Florida fruit Fig. 4 has been prepared showing the two high scoring processes only.

It is immediately evident from this curve that the behavior patterns of the products from the two localities are quite different.

B. *Effect of Maturity.*

In an effort to determine the behavior patterns of the various basic processes as related to fruit maturity, Fig. 5 has been prepared.

Because of the limited number of samples available, these studies were only carried out over a 4-month period. It is interesting to note the apparent change in behavior patterns as the season progresses. Here again,

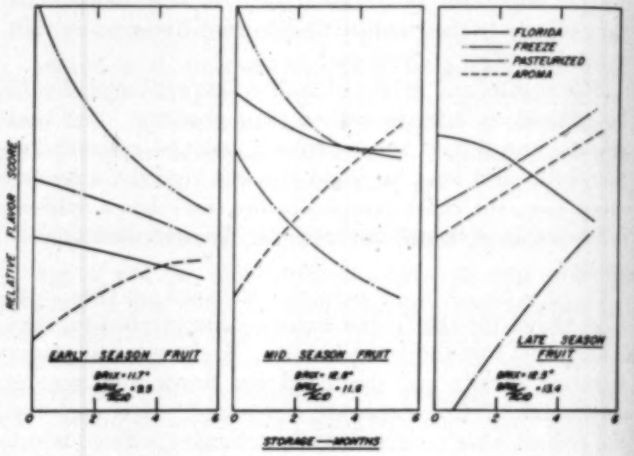

FIG. 5. Study of fruit maturity relative to processing methods for Florida Valencia.

it would appear that the freeze concentration technique is superior to other processes throughout the season. The Florida process suffers with the use of early season fruit due to the fact that it is dependent for its superiority on the quality of aroma carried into the juice by the small percentage of cutback juice added to the concentrate. Since aroma is low in early season fruit, it is to be expected that this particular process would fall below normal quality.

The unnatural character of aromatic fraction recovered from the flash evaporation-aroma process, makes this particular process receive a lower score as the percentage of aroma increases throughout the season, with the score actually improving as storage changes modify the unpleasant aroma character. In much the same manner the overripe aroma in the frozen concentrate and the cooked flavor in pasteurized concentrate are modified on storage to become more acceptable whenever late season fruit is used. Obviously, a study of these behavior patterns requires mass repetitive data over a period of years. It may be theorized, however, that characteristic process flavors may be influenced by the maturity of the fruit and the storage pattern of the product may change, depending upon maturity variations.

In order to further show the effect of fruit maturity, the California experiments were broken down into two groups. The first of these included all shpiments with a low Brix/Acid ratio, averaging 9.4, and the second included all shipments with a high Brix/Acid ratio, averaging 11.2. These data have been tabulated in Table 2.

TABLE 2

Study of Fruit Maturity Relative to Processing Methods on California Valencias—No Storage

Brix/Acid Ratio	Average Brix	Taste Score			
		Aroma Process	Pasteur. Process	Freeze Process	Florida Process
9.4	12.3	6.0	4.7	3.2	5.7
11.2	12.0	6.2	5.8	5.6	6.5

Here again, there is noted the different behavior pattern between California and Florida fruit. In this particular case, the "grassy" character, along with a slightly bitter character, was noticeably prevalent in early season fruit, which resulted in a scoring downward of those particular processes where the juice is treated most gently, notably the Freeze Concentration Process. As the fruit matures and the Brix/Acid ratio increases, the degree of grassiness or bitterness decreases, resulting in improved scores. However, the same relative pattern between processes prevails.

Another factor that should be noted in comparing the above information is the general agreement among orange processors that in extracting California fruit, particularly in high-speed burring equipment, most of those substances which are responsible for bitterness enter the screened juice. In our experiments, the Freeze Concentrate sample was made with burred juice to avoid a high peel oil level. It is possible that this may have influenced the relatively low scores for this particular process.

C. *Effect of Evaporation Temperatures*

The effect of concentration temperature on the final flavor and the storage characteristics of the product was studied with both California and Florida juice.

Very low temperature evaporation runs were made by ice sublimation techniques and represent an ideal approach to the problem. The laboratory data are not too conclusive; they indicate a slight reduction in quality due to evaporating at —4° F. (—20° C.) as compared to 77° F. (25° C.), a leveling off at a lower flavor level between 77° F. and 95° F., and a significant drop when the temperature of evaporation goes beyond 95° F. (35° C.). Because of the difficulties inherent in running such experiments on laboratory size quantities, the inferences drawn from these laboratory observations have been subsequently checked in pilot plant size equipment over some rather extensive operating runs. All of the data seem to support the conclusion that an upper limit of about 95° F. (35° C.) for concentration temperature is imperative for the prevention of cooked flavor in the freshly processed samples.

Cooked flavor identified on initial testing has been equally prominent on storage. No cooked flavor has developed during storage which was not present on initial sampling. Samples prepared by Freeze Concentration show a better average score than those prepared by any conventional evaporator within practical evaporating temperatures. Evaporating temperatures above 95° F. (35° C.) should be avoided.

D. *Effect of Rate of Freezing*

The rate of freezing of the finished product was studied by freezing vacuum canned samples in (a) acetone and dry ice, (b) agitated air at 32° F. (0° C.), (c) still air at 0° F. (—18° C.) with the cans closely packed, (d) still air at 32° F. (0° C.) for 24 hours, then 0° F. (—18° C.) air.

Results available from this series as well as from additional and more comprehensive data on both pilot plant and commercial size operations do not show any significant differences for reasonable commercial freezing rates. It was therefore concluded that normal blast freezing, immersion freezing, or cold room freezing, would result in no adverse qualities appearing in the products if normal bacteriological and enzymatic precautions were observed.

E. *Effect of Added Sugar*

Taste test results on undermature fruit indicated low acceptability, particularly for the Florida process, with specific criticism of high acidity. Samples were packed in which the low Brix/Acid ratio was adjusted to 13 by the addition of sucrose. Taste test averages did not show a distinct preference for the adjusted series. It is felt, however, that this obesrvation may well be valid for an expert taste panel but not necessarily so if one were attempting to interpret operations in the light of consumer preference rather than expert panels. In addition, the particular season in which these experiments were carried out was unusual in that it did not show the wide variation in Brix/Acid ratios normally expected. It is possible that the results might have been different had the variation been greater.

F. *Effect of Cutback Juice Temperature*

It has been previously said that the quality of the product resulting from the Florida process is to a very large degree dependent upon two factors: (a) the temperature of concentration, and (b) the quality of the cutback juice. The cutback juice in the Florida process is used as a vehicle for carrying aromatics back into the product. It was therefore assumed that the temperatures of this juice at time of reaming and time of blending might well be important factors in the quantity of aroma carried into the finished product. Samples were prepared using

(1) Room temperature oranges and concentrates at 50° F. at time of blending. This represents average plant conditions.

(2) 30° F. oranges blended with 15° F. concentrate, with blending carried out in 32° F. atmosphere.

(3) 32° F. oranges, 55° F. concentrate, blended at room temperature (70° F.). The results are shown in Table 3.

It would appear that low temperature reaming operation in conjunction with low temperature blending operation gives a preferred final frozen product. It is

TABLE 3

The Effect of Juice Temperatures at Time on the Flavor Score of Freshly Prepared Samples—California Valencias

70° F.-Cut-Back 50° F.-Concentrate 70° F.-Blending Rm.	30° F.-Cut-Back 15° F.-Concentrate 0° F.-Blending Rm.	30° F.-Cut-Back 55° F.-Concentrate 70° F.-Blending Rm.
6.4	7.1	6.9

assumed that this is due to the retention of more volatile aromas at the lower temperatures and that it would therefore be desirable to cool cutback juice as rapidly as possible below 32° F. and hold it at low temperatures until the final blending and freezing operation is completed. It would also appear desirable to pre-cool the concentrate before blending in order to obtain maximum quality.

G. *Effect of Deaeration*

The removal of air by vacuum-pot deaeration was found to be only about 70% efficient. In an effort to investigate the influence on initial quality and storage stability of more complete air removal, samples were prepared using a spray type deaerator, which was found to be effective to the point of 97% air removal. Results on freshly prepared samples averaged a flavor score of 6.7 for the undeaerated product and 5.8 for the thoroughly deaerated samples. A study of the scores and comments led to the conclusion that this difference in initial quality was probably due to definite and readily distinguishable losses in flavor and aroma which accompanied the thorough deaeration. Storage observations showed the two products leveling out at approximately the same point after one year.

It has been the authors' privilege to examine similarly deaerated products prepared at the Citrus Experiment Station in Winter Haven, Florida, and at the University of Florida Experiment Station in Gainesville with similar conclusions.

U. S. Patent No. 2,453,109, MacDowell, Moore and Atkins, assigned to the United States of America, includes deaeration as an operating step in each of their claims.

The conclusion drawn from experiments reported here would disagree with this, suggesting that ordinary commercial deaeration operations are more effective in removing aromas than in removing air with the net result that initial product quality suffers and storage characteristics are not materially improved.

H. *Effect of Vacuum Packing vs. Air Packing*

Quite a bit has already been published on the air packing of frozen orange juice concentrate versus packing in vacuum. The normal commercial operation today includes votating the concentrate to a slush-frozen condition before filling into the containers. This may whip air into the product which cannot be readily removed by the flash-type vacuum canning equipment.

In order to approach the problem from a strictly theoretical point of view, liquid concentrate at 38° to 40° F. was filled into containers and the product sealed (a) without evacuation, and (b) with a 28-inch vacuum on the vacuum sealing chamber. Results are summarized in Table 4.

TABLE 4

Effect of Packing Method on Flavor Score and Storage Characteristics of California Valencias

Storage Time in Months	Type Pack		
	Bottle Pack (Air)	Can Pack (Air)	Can Pack (Vacuum)
0	5.3	5.5	7.0
4	....	5.5	6.1
6	....	4.9	5.8
8	....	5.0	6.0
12	....	5.2	5.8

These results would indicate a distinct preference for vacuum packed samples over air packed samples throughout most of a 12-month storage period. However, the vacuum pack appears eventually to reach the same level as the air pack, probably due to the dissolved gases in the juice itself. No effort was made to remove these during packing, and the flash vacuum before crimping is of insufficient duration to do an effective over-all job.

I. *Effect of Adding Back Condensed Aroma*

Experiments on aroma recovery were made to find a method of (a) recovering and (b) preserving the volatile flavors of fresh orange juice. In one series of experiments the first 10 percent of distillate from vacuum concentration was recovered by means of low temperature condensation and added to a 6:1 concentrate to bring it back to 40° Brix. In another experiment a similar operation was carried out, and in addition Vitamin C was added to the distillate recovery flask to the extent of 1/10% ascorbic acid based on the total fresh juice. In a third experiment the distillate obtained in the first method was concentrated 10-fold, added to the 6:1 concentrate and this product then brought back to 40° Brix with cutback juice. Other variations were also tried. The second and third techniques mentioned above were voted consistently superior to the other samples. In general, however, none of these results were sufficiently outstanding on freshly prepared samples to justify more extensive exploration and, in fact, on storage most of the samples developed objectionable strawberry or apricot-like characteristics which were entirely foreign to orange juice.

J. *Effect of Cutback Juice*

Throughout this report, where the term cutback juice has been used, it has referred to the operation of concentrating the base product sufficiently beyond 40° Brix to permit of the introduction of at least 10% freshly reamed, unpasteurized, undeaerated juice. This technique, originally recommended by the Florida Citrus Commission with slight modifications, has the effect of reintroducing into the vacuum concentrate enough of the natural fresh fruit characteristics and aroma to make the product a very close duplication of fresh juice when properly reconstituted. In order to study the effect of this cutback juice addition on flavor score and stored samples, 40° Brix concentrates were made by direct evaporation and then canned and frozen without any cutback juice. This product was compared with the normal Florida process product wherein the

concentrate was evaporated to 55° Brix and then brought back to 40° Brix with freshly reamed single strength juice. Results are shown on Fig. 6.

It is obvious from the curve that a positive flavor contribution is made by the addition of cutback juice, both initially and over the entire storage period. Similar tests were carried out on California Valencias, data for which are not shown but the pattern revealed is essentially the same. These data confirmed the observations of the Florida Citrus Commission and substantiate their recommendation for inclusion of cutback juice in frozen

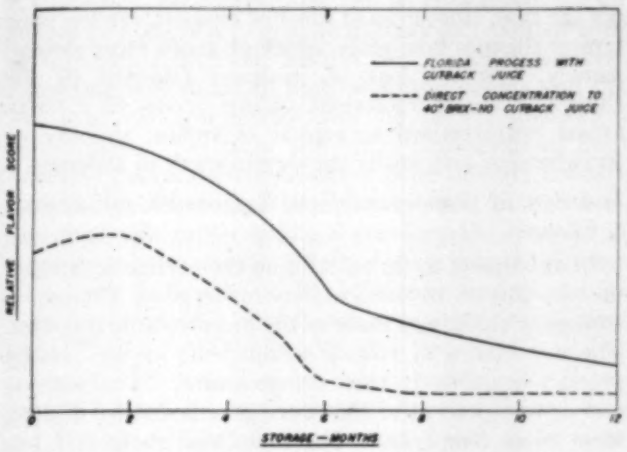
FLORIDA PROCESS WITH CUTBACK JUICE
DIRECT CONCENTRATION TO 40° BRIX-NO CUTBACK JUICE
RELATIVE FLAVOR SCORE
STORAGE—MONTHS

FIG. 6. Effect of cutback juice on initial quality and storage life of orange juice concentrate using Florida Valencias.

orange juice concentrates. No laboratory data are available to show the effect of varying amounts of cutback juice, since it was impossible to get concentrates beyond 60° Brix without encountering serious viscosity increases and reduced heat transfer rates which produced a cooked flavor. However, the additional quantity of cutback juice that could be added by concentration to 60° Brix rather than 55° Brix was either insufficient in these tests to produce a discernible flavor difference or the deterioration in quality of the concentrate due to possible heat damage offset the positive effects of additional cutback juice. This area is worthy of further investigation.

K. *Effect of Added Orange Oil*

There has been considerable discussion about the merits of high oil concentrates versus low oil concentrates, a problem which largely revolves around eventual consumer acceptance of the product. In an effort to accumulate data on this factor, samples were prepared in which the juice was carefully burred and an effort made to obtain an extremely low oil content raw juice. Concentrates with added cutback juice were made from this raw juice and modified as follows:

(1) Contained no added oil
(2) Contained .0018% by weight of 5-fold concentrated orange oil
(3) Contained .008% of single strength orange oil

These levels of acceptability were established by taste tests using the expert panel, and the oil used was highest quality California Citrus Exchange oil. From past experience these oils have been demonstrated as being essentially completely stable at —10° F. and it was felt that products with these additives might well be preferred to bland or unnatural flavors occurring in the stored samples of the basic series. Results are shown in Fig. 7.

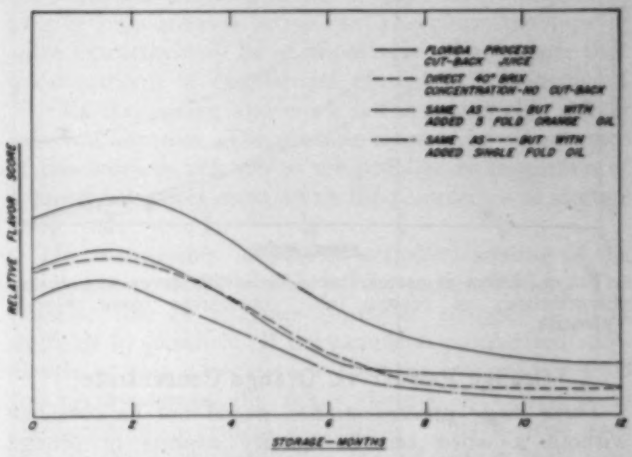
FLORIDA PROCESS CUT-BACK JUICE
DIRECT 40° BRIX CONCENTRATION-NO CUT-BACK
SAME AS ---- BUT WITH ADDED 5 FOLD ORANGE OIL
SAME AS ---- BUT WITH ADDED SINGLE FOLD OIL
RELATIVE FLAVOR SCORE
STORAGE—MONTHS

FIG. 7. Effect of addition of stable orange flavor oil on initial flavor and storage quality of orange juice concentrate using California Valencias.

It is obvious from the data that no advantage was gained by the addition of such oils insofar as our expert panels were concerned either with relation to initial quality or storage stability. It is interesting to note that the products with and without oil followed parallel behavior patterns. It was therefore concluded that added oil makes no contribution to stability.

L. *Effect of Pasteurization*

In general, it has been the authors' experience that pasteurization, no matter how carefully handled by existing commercial techniques, can be readily detected in finished products. In order to accumulate objective data on this observation, samples were compared in which (a) neither concentrate nor cutback juice was pasteurized except to the extent the concentrate was heat treated during evaporation, (b) the concentrate was pasteurized before concentration and unpasteurized cutback juice was added as the diluent, and (c) both the raw juice for concentration and the raw juice for cutback were pasteurized prior to use. The data are shown in Fig. 8.

These data would seem to support the conclusion that the best product is made when no pasteurization is used and that pasteurization of the cutback juice is readily discernible initially, but appears to level off on storage. The low initial score for a completely pasteurized product represents a sufficient number of tests to have statistical significance and we believe is attributable to the recognizable cooked flavor. This cooked flavor mellows itself on storage, producing the apparent flavor improvement noted on the curve. It is believed that these data differ from those accumulated in the Florida Citrus Experiment Station where pasteurization was felt to have a less marked effect upon initial flavor than reported herein.

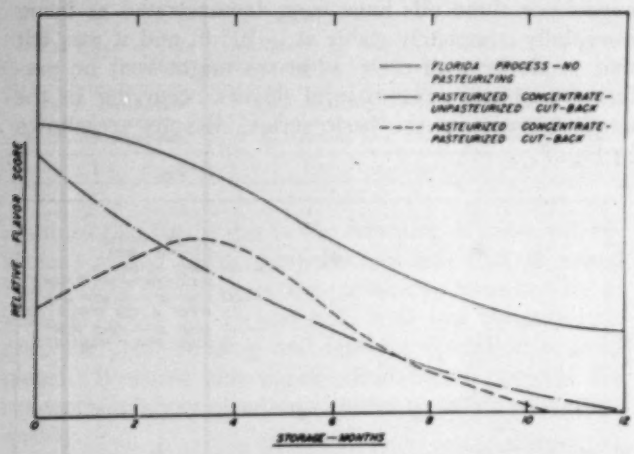
FLORIDA PROCESS – NO PASTEURIZING
PASTEURIZED CONCENTRATE – UNPASTEURIZED CUT-BACK
PASTEURIZED CONCENTRATE – PASTEURIZED CUT-BACK
RELATIVE FLAVOR SCORE
STORAGE – MONTHS

FIG. 8. Effect of pasteurization on initial flavor and storage characteristics of orange juice concentrate using Florida Valencias.

Orange Powder vs. Orange Concentrate

These basic process studies would not be complete without a word on the quality aspects of orange juice powder. A very intensive study of the initial quality and storage characteristics of low temperature (lyophilized) powders was made as the result of a process offered for sale to General Foods Corporation. Process details must remain confidential, but it can be pointed out that several hundred samples of sublimation dried orange powders were prepared by methods cited in the literature as well as by the method under consideration. These products were compared with fresh juice and commercial frozen concentrate. Average scores for the products were:

1. Fresh juice—8.4-8.8
2. Commercial Frozen Concentrate—7.3-7.6
3. Powdered Orange Juice Samples—5.7-6.3[*]
   Range—(4.9-7.6)

On the basis of these results it is difficult to see how powdered orange juice can offer the concentrates any serious competition with the present concept of the art.

Fundamental Investigations in Flavor Changes

Quite a few other variables have been studied than those reported on the above, but at the present time only inadequate data are available. Among the things covered were (1) the method of extraction of the juice as related to initial and storage characteristics, (2) the addition of pulp to the juice in varying levels, also in relation to initial and storage characteristics, (3) the study of Florida fruit varieties, and (4) the study of antioxidants and gas processing as a means of controlling off-flavors which develop on storage.

The results of these early tests, as well as more recent market experiences only served to emphasize the need for further intensive investigation into the causes of storage changes and means for delaying or inhibiting these changes. A comprehensive program on this problem was developed which is still being very actively pursued. Some of the factors being investigated and the results and conclusions to date are reported below:

Effect of Storage Temperature on Flavor Change

The effect of storage temperature on the rate of flavor change of single strength juice has been surveyed and it was noted, as might well be anticipated, that the higher the storage temperature, the more rapid the rate of change; an observation paralleling those reported already for canned commercial orange juice. A temperature of —40° F. was employed with the hope that at this point the rate would be so slow as to be negligible and samples so stored could serve as controls. This was not the case, since even at this low temperature the same typical changes take place, although much more slowly; namely, first the loss of freshness followed by the change of the characteristic orange aroma to a fruity aroma characterized as typical of apples, apricots, or strawberries, and finally the development of staleness.

Isolation of Component Part Responsible for Storage Change

In an attempt to throw light on the particular fraction or constituents of orange juice undergoing change on storage, a study was made of the more volatile fractions. The importance of volatile components in the finished product has already been demonstrated. If as little as one or two percent of the water is removed by flashing from room temperature into a vacuum there is a loss of sufficient volatiles to be damaging to fresh quality. More extensive evaporation progressively removes the volatile fraction and finally results in a product having no off flavors if heat damage is avoided but conspicuously lacking in freshness and characteristic orange aroma. Fig. 9 presents the data on single strength juice (100% volatiles) and concentrates having varying proportions of the volatile fraction added back to them as single strength cutback juice.

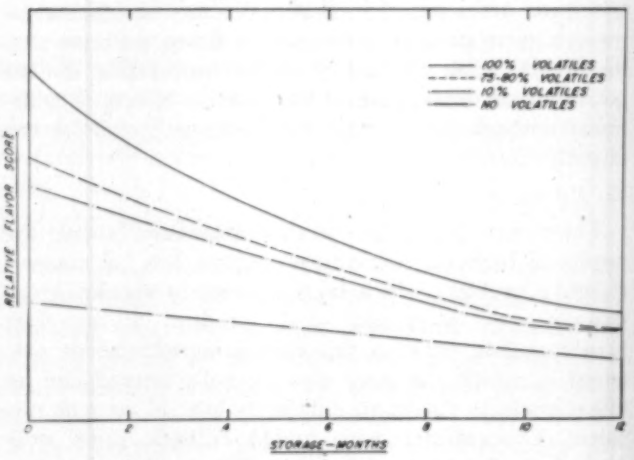

FIG. 9. Effect of increasing volatiles on initial quality and storage behavior of orange juice.

It is noted that the base concentrate stripped of volatiles had a relatively low rating when fresh and the product underwent comparatively little change during storage. Concentrates containing volatile fractions changed in storage roughly in proportion to their volatile content. These data have been confirmed by a study

[*] This score represents 0° F. storage. Powder stored at 70° F. vas completely unacceptable in less than 30 days.

of the volatile fraction, collected from stored concentrate by distillation techniques. The characteristic flavors of the stored product could be distilled off and recovered in the condensate, leaving a relatively bland base concentrate with a low flavor rating. It would, therefore, appear that the storage changes previously noted are associated directly with the more volatile components. Insofar as present commercial processes are concerned, further investigations should be directed at the cutback juice rather than the concentrate.

Flavor Changes Induced by Microorganisms

Obviously, microorganisms can be responsible for off flavors in juice if it is grossly mishandled. Rotted fruit or fruit stored wet and held in this condition prior to extracting will result in high organism counts and the flavor of the concentrate will be scored downward accordingly. Pilot plant and factory observations have indicated that under conditions of good sanitary practice and continuous storage in a frozen state, orange concentrates will still contain a considerable number of organisms. The possible effect of these microorganisms directly or indirectly on flavor change during storage were investigated. Sound sterile oranges were introduced into a sterile chamber. The juice was expelled, screened, and packed under aseptic conditions. When carefully handled, single strength juice so packed with no chemical or heat treatment was found to be commercially sterile; i.e., it could be stored at room temperature without fermentation, and bacterial counts, if not zero, were in the range of 1 to 3 per milliliter. Storage characteristics of these sterile packs have been found to be essentially the same as commercial packs having microorganism counts of 50,000 to 100,000; normal for good, sanitary commercial scale frozen concentrate operations. These data are shown in Table 5.

TABLE 5

Effect of Microorganisms on Storage Characteristics of Untreated Frozen Single Strength Orange Juice

Plate Count Per Ml. When Freshly Frozen	Taste Scores	
	No Storage	6 Months Storage
237,000	6.2	5.9
None	5.6	5.0
45	6.3	6.1
5	7.1	5.0

It should not be concluded that microorganisms can be neglected in routine plant operation. These data would indicate that microorganisms normally present in the product when good commercial practice is followed have no deleterious influence on flavor or flavor changes. Storage changes normally observed must therefore be attributed to some other factor.

Changes Induced by Enzymatic Action

The role played by enzymes in the deterioration of orange juice in storage is probably twofold: (a) The pectinesterase activity is a factor in the separation or settling of commercial frozen concentrates; (b) Other enzymes are possibly responsible for some flavor changes. The literature indicates that orange juice contains at least peroxidase, pectinesterase, acetylesterase, phosphatose, cytochrome oxidase, and dehydrogenase.

The enzyme content of orange juice varies appreciably with the manner used to express and finish the juice. Pectinesterase is associated with the solid fraction of the juice; methods of expressing juice which macerate the non-juice portions of the orange have been shown to give high enzyme activities. Therefore, the type of juice extractor may be of importance. To support this, a comparison of commercial extractors was made in Florida this spring and work is continuing this season here in California. The possible commercial significance of this work in relation to the problem of separation of commercial juices must await the completion of storage tests.

The relationship of enzyme action to settling of the solids can be easily established by pasteurization. The possible role of enzymes in flavor changes is more diifficult to establish. If the sample is pasteurized sufficiently to give a negative test by the Stevens[4] method for pectinesterase, the flavor damage is extensive as measured by a critical evaluation. This is true even though the pasteurization is carried out at high temperatures with time cycles of heating, holding and cooling as low as 2 and 3 seconds. Other possible methods of enzyme inactivation, such as ultrasonic vibration, have been investigated but to date, under no conditions have the enzymes been inactivated without changing the fresh character of the juice. Conversely, to date no sample of juice with fresh juice flavor has been produced completely free of enzyme activity. Therefore, the possible detrimental effect of enzymes on the flavor components during frozen storage has not been eliminated.

Although it has not been possible to run a conclusive experiment by inactivating enzymes without flavor change, it has been possible to increase the rate of typical flavor change by the addition of enzyme concentrates. It was discovered that when one part of a glucose oxidase concentrate was added to 3000 parts of orange juice, the flavor was changed within one hour, while no detectable change took place in the control samples. The change in flavor induced by glucose oxidase is typical of the flavor change taking place over a period of 6 to 8 months in frozen storage, and is related to the amount of oxygen present in the juice, as illustrated in Table 6.

TABLE 6

Effect of Deoxygenase on Single Strength Orange Juice in Frozen Storage

Treatment	Deoxygenase Added	Flavor Score		
		Fresh	2 Hrs.	8 Mos.
Deaerated, Reamed Juice	None	7.3	7.3	5.0
Deaerated, Reamed Juice	1 Part/1,000	6.3	4.6	....
Undeaerated, Reamed Juice	1 Part/1,000	6.7	4.2	....

The stale flavor so produced can be readily distilled as can the normally staled aroma.

The addition of pectinesterase enzyme concentrates prepared from orange products had no effect on the

[4] Stevens, J. W. Method of Testing Fruit Juices. U. S. Patent 2,267,050, Dec. 23, 1941.

flavor changes under the experimental conditions investigated.

Possible Chemical (Non-Oxidative) Changes

The flavor constitutents of orange juice have been investigated. However, research in this area has been limited to the organic constituents in the volatile fractions. Although there is a possibility that flavor changes may originate in inter-reactions such as transesterification, or cleavage such as hydrolysis, this work has not progressed sufficiently to throw any light on these possibilities.

Oxidative Changes

Oxygen plays an important role in the development of stale flavor of orange juice in frozen storage. This oxidation could be enzymatic, or it may be non-enzymatic, or even both. The fact that oxygen is required for the change is shown in Table 7.

TABLE 7

Effect of Oxygen on Storage Characteristics of Frozen Orange Juice

Treatment	Oxygen	Taste Test Scores	
		Fresh	6 Months Storage
Extracted in Air, Air Packed	213 p.p.m.	7.4	4.2
Extracted in Nitrogen Deaerated with Nitrogen, Reaerated	6 p.p.m.	7.1	5.0
Extracted in Nitrogen, Deaerated with Nitrogen	0.5 p.p.m.	7.4	6.7

The fact that oxygen plays such an important role in this flavor change does not minimize the possible action of oxidative enzymes; on the contrary, it may emphasize the role played by the enzymes.

The fact that commercial packers have reported little or no difference between air pack and vacuum packs cannot be taken to indicate that oxygen is unimportant in storage changes. If the juice is exposed to air throughout the course of the present commercial operation and contains incorporated air when packed, there will be little or no advantage in so-called vacuum packing at 10 to 15 inches of vacuum. The amount of exposure to atmospheric oxygen and/or the amount of air sealed in the can is amply sufficient to complete the oxidation of the delicate flavor constituents present in even the best oranges.

Fig. 10 indicates the amount of air that can originate in the various commercial process stages. Current research is showing that the critical oxygen level necessary to effect deterioration of flavor is very low and that

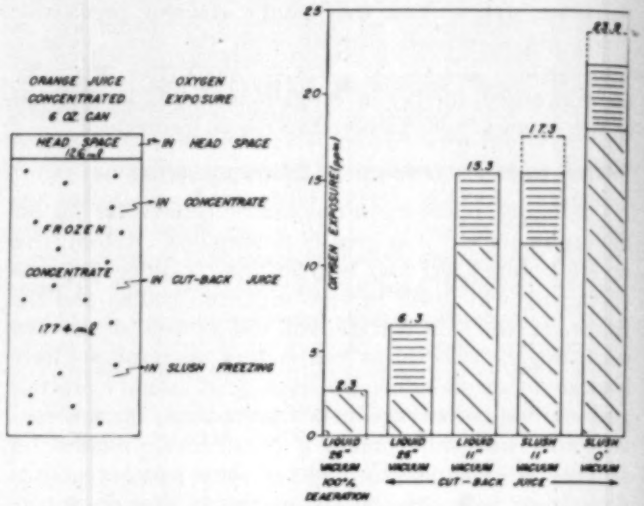

FIG. 10. Oxygen exposure of canned orange juice concentrate.

research data and recommendations on oxidative deterioration reported years ago for canned heat processed single strength orange juice may be equally applicable to the frozen concentrate industry.

Acknowledgment

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Sirup Treatment of Apple Slices for Freezing Preservation[a]

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Vacuum impregnation of apple slices with sugar sirups has been studied and the product of this pre-freezing treatment has been compared with that from steam blanching and from sulfiting. Generally, the product of sirup filling was equal or superior to that of steam blanching and sulfiting, but most improvement over these processes was noted in the softer varieties.

[a] Presented before the Ninth Annual I. F. T. Convention, San Francisco, California, July 12, 1949.

[b] Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

Introduction

The common methods for pretreating apple slices for freezing preservation are principally designed for the prevention of browning after freezing and thawing. Although several methods are available, including the use of ascorbic acid *(1)*, the usual commercial treatments involve steam blanching of the slices at 210° to 212° F. for sufficient length of time to prevent browning, or dipping in solutions of sulfur dioxide or its derivatives *(2, 6, 7, 8, 10)*.

However, the use of either steam blanching or of

sulfur dioxide is subject to criticism. Although steam-blanched slices usually have good color, it has been shown *(5)* that the heat treatment required causes large losses in soluble solids. In addition, it is known that blanching causes excessive softening (especially in the softer varieties) and flavor changes. The sulfur dioxide treatment produces a satisfactory product in respect to color, but generally the amounts necessary for satisfactory color retention during freezing and subsequent thawing cause an after-taste which is objectionable to some people. The treatment to be described has been devised to prevent the browning of apple slices after freezing and thawing; at the same time it produces a product with more desirable flavor, texture, and drip characteristics than that resulting from the usual procedures. This treatment called "sirup filling" consists of removal of tissue gases from the slices by the use of a vacuum, followed by partial replacement of voids with sugar sirup containing a small amount of antioxidant.

Grab and Haynes *(3)* have recently described a method involving pretreatment of apple slices in a vacuum with a sucrose sirup containing a small quantity of ascorbic acid. Although this method is very similar to sirup-filling, the following report on the treatment as applied to western apples includes additional quantitative data. Vacuum treatment of sliced apples is included in certain patented processes.

The investigations carried out in the development of the sirup-filling treatment can be conveniently divided into two distinct phases: First, a study has been made of the mechanics of the treatment, including changes in weight and in soluble solids of the apple slices and of the sirup. Second, organoleptic appraisal of the product has been carried out by comparing it with corresponding products resulting from usual steam blanching and sulfiting procedures.

Mechanics of Sirup Filling

Procedure: Delicious, Gravenstein, Pippin, and McIntosh varieties were used in most of the work. The apples (from 33° F. storage) were mechanically peeled, cored, and sliced (twelfths) directly into 1 percent NaCl solution, where they were held 3 to 5 minutes. The slices were then drained in a stainless-steel wire basket for 2 minutes, weighed, and completely submerged in an equal part by weight of sirup containing an antioxidant and then subjected to a vacuum of 29 inches of mercury for 2 to 3 minutes. The vacuum was broken with air and the fruit was held undisturbed for a short period to permit penetration of sirup into the slices. Next, the slices were removed from the sirup and drained for 1 or 2 minutes until relatively free from excess sirup. The drained slices were then packaged in sanitary-type tinned cans, sealed, frozen, and stored at —10° F.

The soluble solids in the sirups and apples were determined by refractometer both before and after treatment. Three hundred gram samples of apples were homogenized in a blender for about 5 minutes in preparation for the determinations.

As vacuum is applied to a sirup solution in which apple slices are submerged, air begins to leave the tissue when the vacuum gauge reads approximately 10 inches and bubbling steadily increases up to 29 inches, at which point most of the air is removed in 2 to 3 minutes. A vacuum of 25 inches may be sufficient for fully ripe, soft varieties. When the vacuum is released, the sirup solution tends to fill the spaces or voids previously occupied by the gases to an extent dependent on the nature of the solution, the physical characteristics of the apple, and the "residence time" of the slices in the sirup.

TABLE 1

Weight Changes Resulting from Vacuum Impregnation of Sliced Apples with Sucrose Sirups [a]

Variety	Season	Initial percentage sucrose in solution	Percentage increase
Delicious	1946	0	27
Delicious	1946	20	16
Delicious	1946	40	7
Delicious	1946	60	5
Delicious	1946	20	13
Delicious	1946	40	4
Delicious	1946	60	4
Delicious	1948	20	12
Delicious	1948	30	8
Delicious	1948	40	9
Delicious	1948	60	9
Pippin	1948	20	10
Pippin	1948	30	10
Pippin	1948	40	4
Pippin	1948	60	7

[a] Sample weights ranged from 3.8 to 7.5 pounds of apple slices per batch.

The effect of the nature of the solution is illustrated in Table 1, where it is seen that the greatest percentage of weight gain occurs with water. As the sucrose content of the impregnating solution is increased, the percentage weight gain of the slices tends to decrease. This progressive variation (which becomes negligible at the higher sucrose concentrations) is presumably the result of variations in (a) penetration of liquid and in (b) osmotic effects. Although the samples treated with 20 percent sirup showed greater weight increases, the slices impregnated with 40 to 60 percent sirup gained two to three times as much in soluble solids. Generally the soluble solids of slices treated with the heavier sirups were approximately doubled. On cross-sectioning, water-filled slices usually are translucent throughout, showing complete penetration of the liquid, whereas sirup-filled slices are generally opaque except for a narrow band around the surface. A relatively greater loss of water from the slices to the more concentrated sirup solutions due to osmosis might also be expected.

TABLE 2

Weight Changes Resulting from Vacuum Impregnation with 50 Percent Sucrose Sirup [a]

Variety	Percentage increase
Cortland	2.5
McIntosh	4.2
Golden Delicious	5.7
Gravenstein	6.5
Rome Beauty	7.3
Common Delicious	7.5
Red Delicious	7.6
Pippin	7.7
Winesap	12.2
Jonathan	12.3

[a] Sample weights ranged from 10 to 25 pounds per batch.

The effect of variety of apples is illustrated in Table 2. Although seasonal, geographical, and cultural conditions may profoundly affect these results, Table 2 indicates that variety is one of the most important factors influencing weight pick-up from sugar solutions. Within a given variety, it has been found that the use of riper, softer fruit results in a greater weight pick-up and easier penetration, but soft varieties such as Cortland and McIntosh picked up much less weight than well-known hard varieties such as Winesap and Newtown Pippin. Hence the easily discernible textural differences encountered among varieties cannot be relied on to indicate the relative weight changes associated with the process. The results are probably due to the uniqueness of the structural makeup of each variety.

The effects of "residence time" depend upon variety and maturity. For varieties whose structure permits only minor sirup absorption, the predominating effect will be a weight loss, apparently due to osmosis, and this weight loss will increase with increasing time of submersion (Table 3). On the other hand, varieties

TABLE 3

Effect of "Residence Time" on Weight Changes of Hard, Immature Gravenstein Apples [a]

Residence time	Initial sucrose in sirup	Percentage loss
	%	
20 minutes	60	3.4
60 minutes	60	6.8
60 minutes	60	5.4

[a] Sample weights ranged from 5.7 to 6.4 pounds per batch.

which absorb relatively large quantities of sirup will show a weight gain, even after long exposure times (Figures 1 and 2). Apparently in this case penetration of sirup slowly increases with increasing "residence time" modified to varying degrees by increasing viscosity of sirup and by increasing rates of water removal due to osmosis.

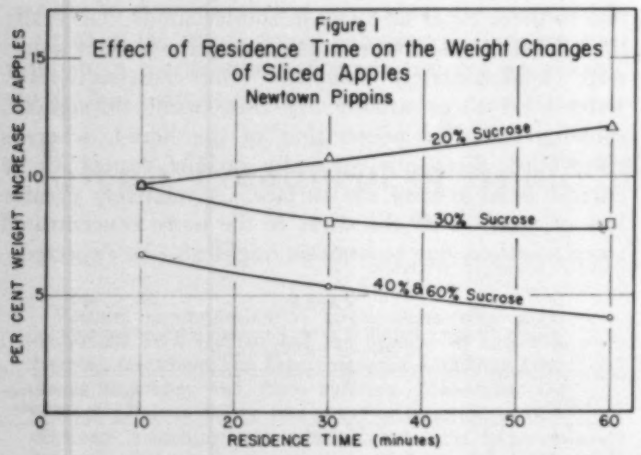
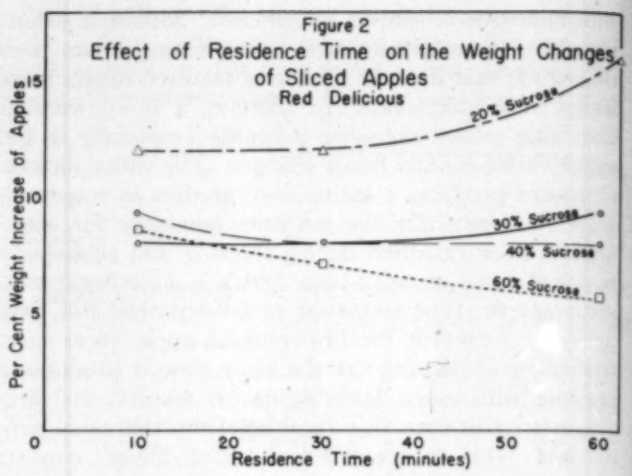


Figure 1
Effect of Residence Time on the Weight Changes of Sliced Apples
Newtown Pippins
20% Sucrose
30% Sucrose
40% & 60% Sucrose
PER CENT WEIGHT INCREASE OF APPLES
RESIDENCE TIME (minutes)

Changes in the sirup depend, of course, upon the ratio of sirup to apple slices. In order to insure complete coverage of the slices, approximately one part by weight of sirup is used for each part of fruit. Under these conditions, the most pronounced change in the sirup is a lowering in density, the decrease being dependent on



the "residence time" of the apple slices (Figure 3). The greatest change in density of sirup always takes place shortly after the fruit and the sirup are mixed; further decreases become smaller and smaller with increasing time. Thus, it appears that the first dilution is due to surface moisture and that subsequent dilution is a result of osmotic action.

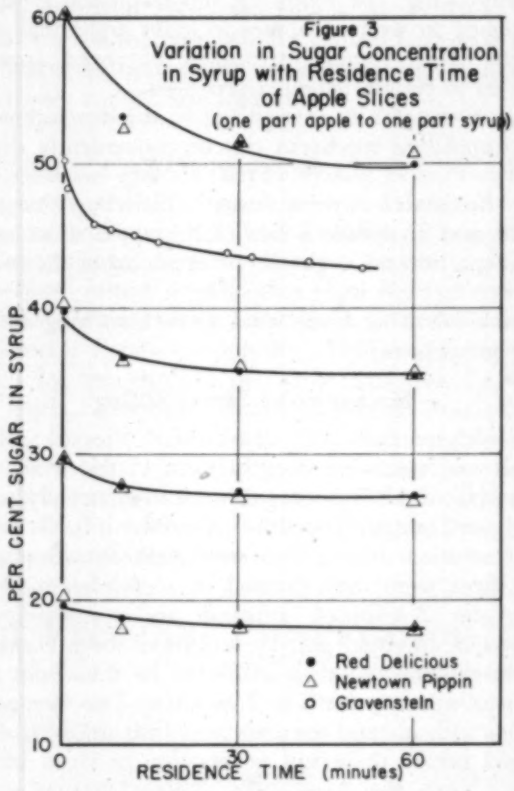


Figure 3
Variation in Sugar Concentration in Syrup with Residence Time of Apple Slices
(one part apple to one part syrup)
PER CENT SUGAR IN SYRUP
RESIDENCE TIME (minutes)
Red Delicious
Newtown Pippin
Gravensteln

Another important change is a decrease or increase in volume of the sirup. Since most of the varieties tested absorbed an appreciable amount of sirup during the process, a reduction in volume generally resulted. In those cases where little absorption took place, sirup volume usually increased.

During the evacuation of certain varieties, considerable frothing above the liquid level of sirup occurred, materially reducing the capacity of the containing vessel. In order to overcome this difficulty, the slices

can be evacuated in the absence of sirup and the vacuum broken with sirup. This procedure not only eliminates frothing, but also facilitates removal of air from the slices and reduces contact time between apples and sirup *(1)*. The later factor may be important in varieties that tend to lose weight in heavy sirups *(3)*.

Both ascorbic acid (0.2 to 0.3 percent in conjunction with 0.2 to 0.3 percent NaCl or 0.5 to 1.0 percent citric acid) and sodium bisulfite (200 to 300 p.p.m. SO_2) have been used satisfactorily as antioxidants added to the sirups. The main reason for reduction in the amount of SO_2 needed when the sirup filling process is used is the fact that much of the oxygen is removed from the apple tissue and thus, interior discoloration is no longer a problem. Moreover, the removal of air greatly speeds up the penetration of antioxidant.

Continuous Sirup Filling: Since sirup filling is essentially a batch treatment it is subject to the limitations and disadvantages inherent in such operations. Consequently it was decided to investigate the possibility of a continuous procedure. The sliced apples were dipped in sirup containing antioxidant, drained, packed in sanitary-type tinned cans, and sealed under a vacuum of 29 inches of mercury prior to freezing. This procedure accomplishes the main purpose of sirup filling, namely the removal of gases from the apple tissue. When the slices are allowed to thaw under vacuum, the voids are apparently sealed up by the melting sirup, aided by partial collapse of the evacuated tissue. Discoloration has not been observed in a period as long as 24 hours after defrosting, even if no antioxidant is added, provided the can is not opened during this time. In order to prevent surface browning after opening and during baking in pies, however, small amounts of ascorbic acid (0.1 to 0.2 percent) or sulfur dioxide (100 to 200 p.p.m. as $NaHSO_3$) in the dipping solution is necessary.

If the container leaks or is opened prior to defrosting, oxygen will reenter the tissue and rapid browning will occur throughout the interior of the slices during thawing. Hence the success of this procedure is entirely dependent upon the ability to maintain a vacuum in the container throughout the storage period.

The film of sirup acquired during the dipping step increases the weight of the apples up to 3 percent and raises the soluble solids of the fruit by 3.5 to 5.5 percent.

Comparison of the Products from Sirup-Filling with Those from Sulfiting and Steam Blanching

Procedure: Slices from several varieties of apples were treated by the batch sirup-filling treatment and compared with corresponding slices prepared by (a) the continuous sirup-filling procedure, consisting of dipping 5 minutes in 50 to 60 percent sucrose sirup containing 0.2 to 0.3 percent ascorbic acid, followed by draining, packaging, and sealing under a vacuum of 29 inches of mercury, (b) sulfiting by dipping 2 minutes in a solution of 0.2 to 0.25 percent SO_2(added as $NaHSO_3$ and adjusted to pH 3.0 with citric acid), and (c) steam blanching 5 minutes at 210 to 212° F. followed by fog-air cooling for 3 minutes. In all treatments, the drained slices were packaged in sanitary-type tinned cans, sealed, frozen, and stored at —10° F. before evaluation. After thawing under standardized conditions, the slices were baked in pies at 475° F. and appraised by a panel of trained judges.

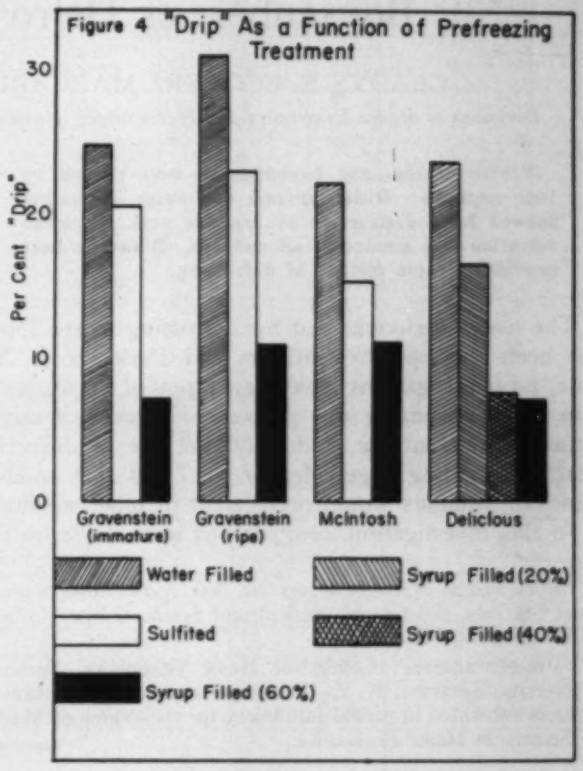
The amount of drip or leakage was determined by weighing the juices collected from thawed slices after a 5-minute draining period on an 8-mesh screen. The slices were defrosted for 3½ hours under running tap water in their original sealed containers.

Results of Comparison: The greatest overall improvement due to sirup-filling was observed in soft varieties such as Gravenstein, McIntosh, Cortland, and Rome Beauty. The baked fruit from sulfited or blanched slices prepared from these varieties was essentially a mushy sauce lacking in flavor, whereas the sirup-filled slices, though soft, retained their normal shape and appearance as well as most of their natural fresh flavor. As might be expected, slices treated with 40 to 60 percent sirup had a firmer texture and better appearance than those which were impregnated with 20 percent sirup.

In the case of Winesaps and Pippins, the texture of slices prepared by sirup filling was not appreciably improved over that resulting from steam blanching or sulfiting; neither of these latter two processes seems to weaken seriously the structure of hard apples. However, for all varieties tested, the flavor of the sirup-filled samples was eminently superior to comparable slices blanched in steam.

Sirup filling also prevented the vigorous frothing and boiling over, which frequently occurs during the baking in pies of sulfited slices of the soft varieties, presumably because of the removal of a large proportion of the tissue gases from the slices during the vacuum process.

The data in Figure 4 clearly demonstrate the superiority of the sirup-filling procedure over other



treatments in prevention of excessive drip or leakage of juice during thawing. Since there is little, if any, replacement of added liquid for gases in the continuous sirup-filling treatment, the drip during defrosting is somewhat less than for the batch procedure.

The flavor, texture, and color of fruit prepared by the continuous sirup-filling treatment were in every way equal or superior to those of comparable fruit prepared by batch treatment.

The final acidity of sirup-filled fruit may be adjusted to any desired value by incorporation of the proper amount of fruit acid in the impregnating sirup. The flavor of Delicious apples was greatly improved by raising the total acidity to approximately 0.4 percent. If desired, additional firmness may be obtained, depending on maturity and storage history, by adding small amounts of calcium salts to the impregnating solution *(4, 9)*. Requirements of the appropriate regulatory agencies must, of course, be met if acid or calcium is added to the product.

Conclusions

Sirup-filling treatment applied to apple slices (either batch or continuous) yields a product with a flavor superior to that resulting from steam blanching or sulfiting; texture of the softer varieties is also greatly improved.

The most satisfactory product results from the use of sugar solutions in the range of 40 to 60 percent sucrose.

With 40 to 60 percent sirup, the resulting drip is considerably less than that resulting from the sulfiting and the steam-blanching treatments.

Acknowledgments

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The Ascorbic Acid and Carotene Content of Frozen Peaches and Boysenberries Defrosted with Dielectric Heat[a]

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Frozen peaches and boysenberries were thawed by four methods. Dielectric and hot water defrosting showed least destruction of ascorbic acid. Carotene retention was similar in all methods. Dielectric heat provides a rapid method of defrosting.

The use of dielectric heat for defrosting frozen foods has been proposed by Cathcart and Parker *(3)*. To date, no investigations have been reported on the vitamin retention during this process. However, it might be assumed from the studies on the use of dielectric heat for scalding vegetables *(4, 6, 7, 8)* that smaller losses of vitamins would occur than in other methods.

In this investigation, comparisons were made on the ascorbic acid and carotene content of frozen peaches and boysenberries defrosted by dielectric heat and by conventional methods.

Experimental Procedure

Defrosting Methods: The Mann-Russell generator[c] used for dielectric defrosting had a frequency range of approximately 20 to 30 megacycles. The maximum grid rating was 200 milliamperes and the maximum plate working rating 0.7 ampere. The rated power input was 5 to 15 KVA with an output between 5,000 to 15,000 B. T. U. per hour. The generator was connected by 70 inch copper leads to 5 x 6 inch aluminum electrodes in open air. A plate current of 0.3 ampere was used in this study. The air space was ¼ inch and an electric fan was used for air circulation. Further mechanical and electrical details may be found in a publication by Ross *(10)*.

[a] Published as Scientific Paper No. 860, Agricultural Experiment Stations, Institute of Agricultural Sciences, State College of Washington, Pullman.

[b] Present address: College of Home Economics, Syracuse University, Syracuse, N. Y. This paper represents a portion of a thesis submitted in partial fulfillment for the degree of Master of Science in Home Economics.

[c] Manufactured by Northwest Syndicate, Inc., Tacoma, Washington.

The other methods of defrosting included room temperature, 70° F. (21° C.), refrigerator temperature, 36° F. (2° C.) and hot water, 130° F. (54° C.).

One-pound packages of commercially frozen peaches and boysenberries were used. For dielectric defrosting, the frozen fruit was removed from the cellophane bag and placed in a round pyrex dish (6¾" x 1½") between the two electrodes. It was necessary to remove the fruit from the package to eliminate arcing. Localized overheating was also avoided by this arrangement since the more conductive liquid portion melted away from the top electrode and flowed out of the intense electric field. For the other methods the fruit was defrosted in the original cellophane bag. Defrosting was considered complete when the fruit reached a temperature of 40-50° F. (4-10° C.). This required 3 minutes for dielectric defrosting, 4 hours at room temperature, 16 hours at refrigerator temperature and 20 minutes in hot water.

Analytical Procedure: The original ascorbic acid content of the frozen fruit was determined after blending the entire package of fruit as described by Rubin, Jahns and Bauernfeind *(11)*.

Immediately after defrosting, replicate samples, composed of representative mixtures of drained fruit and sirup, were analyzed for ascorbic acid and carotene. With peaches, the reduced ascorbic acid was determined by the Loeffler and Ponting *(5)* method, the dehydroascorbic and total ascorbic acid by the Bolin and Book *(2)* modification of the Roe and Oesterling *(9)* method. Dehydroascorbic acid determinations on peaches made by the Bessey *(1)* and Bolin and Book *(2)* methods gave similar results. For boysenberries, the photocolorimetric procedure described by Rubin, Jahns and Bauernfeind *(11)* was employed.

The Wall and Kelley *(12)* procedure was used for the carotene determinations. Total carotenoids were determined directly on the petroleum solvent (bp. 63-70° C.) extract.

The data were statistically treated by the analysis of variance.

Results

ASCORBIC ACID

The results of the ascorbic acid determinations are summarized in Table 1.

Peaches: Under the conditions of this experiment, the reduced and total ascorbic acid contents of peaches defrosted at room and refrigerator temperatures were significantly lower than those of the fruit defrosted with dielectric heat or hot water. The dehydroascorbic acid content tended to show a similar trend. The total ascorbic acid values for peaches defrosted with dielectric heat and hot water were similar. However, a significantly greater amount of the ascorbic acid was retained as reduced ascorbic acid in the peaches defrosted by hot water than in the peaches dielectrically defrosted.

There was a significant loss of reduced and total ascorbic acid in all methods of defrosting.

TABLE 1

Ascorbic Acid Content in Frozen and Defrosted Peaches and Boysenberries

Fruit	Ascorbic Acid	Number of Samples	Frozen	Defrosted				L. S.	D[1]
				Dielectric	Hot Water	Room Temperature	Refrigerator Temperature	5%	1%
			mg./100 gm.	*mg./100 gm.*	*mg./100 gm.*	*mg./100 gm.*	*mg./100 gm.*		
Peaches	Reduced	12	Mean 26.8 Range 26.3-27.2	18.3 14.6-23.5	22.0 18.5-24.8	17.3 14.3-22.5	17.0 14.2-20.1	0.8	1.0
	Dehydro	12	Mean 15.2 Range 12.4-18.6	18.5 15.2-24.2	16.0 14.1-17.9	14.7 12.0-18.1	15.5 11.6-19.1	0.8	1.1
	Total	12	Mean 38.4 Range 35.8-41.4	33.1 29.5-36.6	32.2 30.6-36.0	27.5 25.0-29.7	27.5 23.0-30.7	1.2	1.6
Boysenberries	Reduced	36	Mean 10.2 Range 8.2-11.7	18.0 10.9-25.7	20.2 8.7-33.2	19.0 12.5-28.1	17.3 7.4-29.4	2.7	NS[2]
	Dehydro	8	Mean 3.6 Range 2.6-4.3	11.2 9.4-13.3	10.3 7.8-11.9	8.7 6.3-12.2	10.0 6.2-12.5	NS[2]	NS[2]
	Total	8	Mean 13.8 Range 11.8-15.0	25.6 23.4-27.3	29.7 26.9-32.0	23.4 19.9-28.2	23.0 13.9-27.5	1.8	2.4

[1] Least difference required for significance between means.
[2] F value from variance analysis non-significant.

TABLE 2

Carotene and Total Carotenoid Content in Defrosted Peaches and Boysenberries

Fruit		Number of Samples	Defrosted[1]			
			Dielectric	Hot Water	Room Temperature	Refrigerator Temperature
			mg./100 gm.	*mg./100 gm.*	*mg./100 gm.*	*mg./100 gm.*
Peaches	Carotene	12	Mean 1.27 Range 1.12-1.52	1.39 0.93-1.82	1.42 0.98-1.67	1.42 1.20-1.82
	Total Carotenoids	12	Mean 1.57 Range 1.34-1.82	1.77 1.21-2.17	1.60 1.05-1.92	1.62 1.45-2.00
Boysenberries	Carotene	12	Mean 0.08 Range 0.05-0.11	0.09 0.05-0.16	0.10 0.03-0.20	0.07 0.04-0.10
	Total Carotenoids	12	Mean 0.27 Range 0.20-0.36	0.23 0.17-0.32	0.24 0.20-0.29	0.26 0.20-0.31

[1] F values from variance analysis showed no significant differences between means.

Boysenberries: The reduced ascorbic acid content of thawed boysenberries varied greatly from package to package as is evidenced by the wide range in values obtained (Table 1). No marked differences in reduced ascorbic acid content were found between the methods of defrosting. The hot water thawed boysenberries showed a significantly higher amount of total ascorbic acid than did the boysenberries defrosted by the other methods.

The ascorbic acid content of the samples blended without previous thawing was significantly lower than in any of the thawed material.

CAROTENE

The carotene and total carotenoid contents of both peaches and boysenberries were not affected by the method of defrosting (Table 2).

Conclusions

Dielectric heat provided a rapid method for defrosting frozen peaches and boysenberries. However, the retention of ascorbic acid and carotene in the dielectric defrosted was no higher than in the hot water thawed fruits.

Acknowledgment

The advice and assistance of Dr. Edward Ross in the operation of the high frequency generator is gratefully acknowledged. Acknowledgment is also made of the facilities and services of the Engineering Experiment Station through which the use of the high frequency generator was made possible.

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Performance Tests on Refrigerator Cars[a]

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The present day refrigerator car which has built-in fans, 3½ to 4 inches of insulation, and bunkers that hold 11,000 pounds of ice, will maintain temperatures of 40° F. or less in transit under usual refrigeration service and 10 to 15° if the ice is salted heavily (30% of ice supply). When used under heater service portable heaters are installed in the bunkers to protect perishables from sub-zero weather. During cool weather, the car is often used as a ventilator without bunker ice.

Many tests have been made of the performance of refrigerator cars operating under the services for which they are used in transporting perishables. The Transportation and Storage Project of the U. S. Department of Agriculture has been concerned with refrigerator car testing over a period of about 40 years and several hundred accompanied tests have been made. In addition to our regular tests, we have participated in cooperative work with the Association of American Railroads on refrigerator car design, the 29th of these tests having been made last summer with peaches from South Carolina to New York. Performance tests have covered a wide variety of fruits and vegetables, many types of services, and great extremes in outdoor temperatures. Cars available for general service have been used for the most part, but new types of cars and equipment are tested as they are developed. We have tried to select for this discussion tests that represent what can be done in common service with the equipment generally available.

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Precooling Service

Precooling fruits and many vegetables prior to shipment has become a general practice in many shipping areas because of the great benefit derived in retarding ripening and decay. Cold storage or precooling rooms are not always available at the shipping point, and because of this the refrigerator car has been used as a pre-

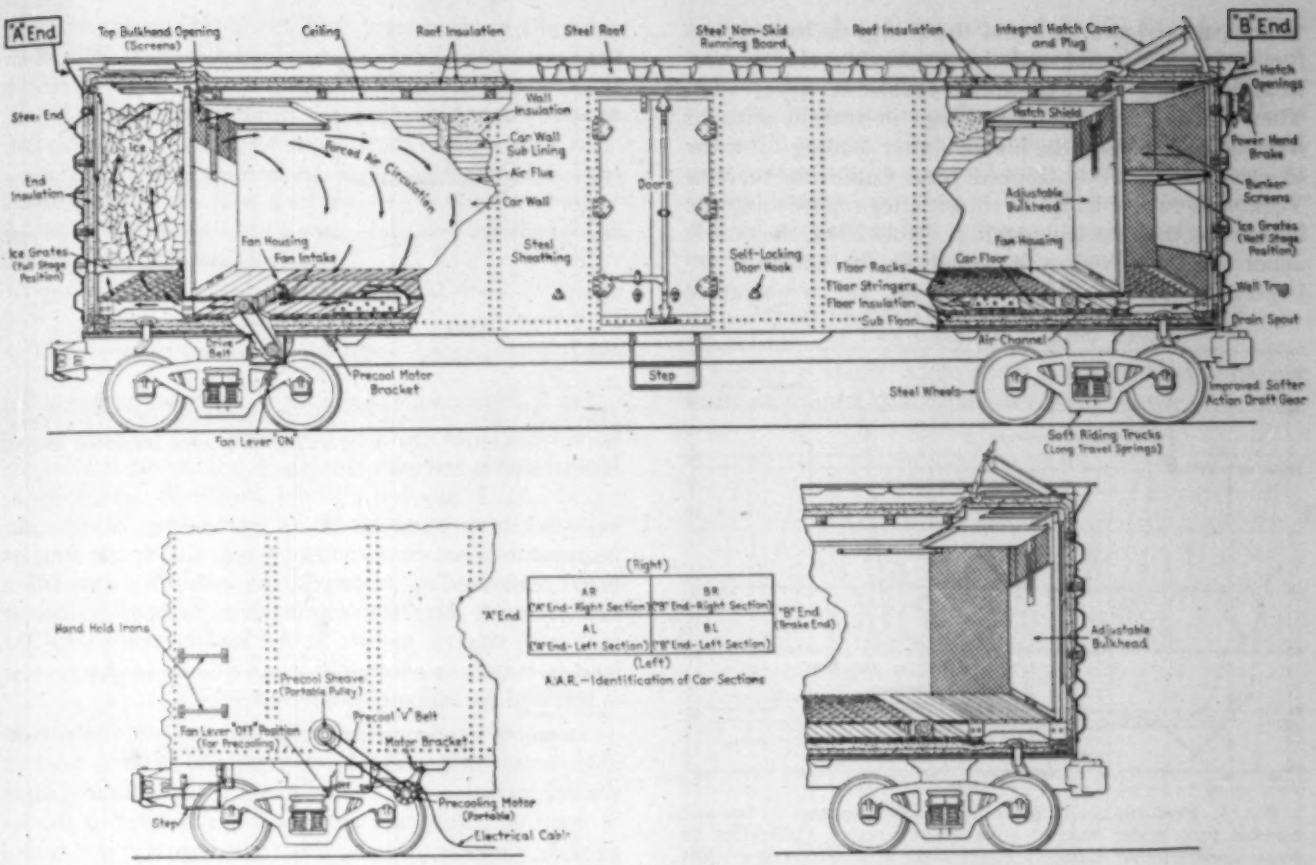

FIG. 1. Sectional drawing showing construction of modern refrigerator car.

cooling plant. The modern fan car has all of the equipment built in it that is needed for a precooling job (Figure 1). Two 1½ h.p. electric motors can be attached to the drive shafts for operating the fans when the car is standing; and if electric power is not avalaible, gasoline motors can be used instead. Figure 2 shows a precooling record made with a Preco fan car. Figure 3 shows a similar precooling test made with portable fans installed in a non-fan car. In both cases approximately 30 degrees of heat were removed from the fruit in 27½ hours. The refrigeration delivered by iced bunkers in some of our precooling tests has been at an exceedingly

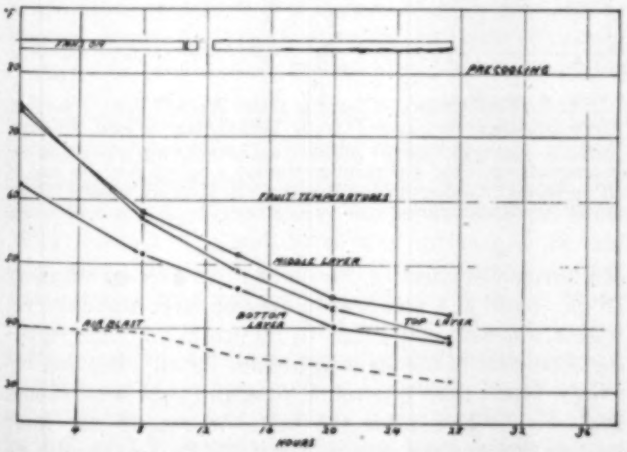

FIG. 2. Rate of precooling obtained in refrigerator car by operating built-in car fans. Heavy load of grapes (34,000 pounds).

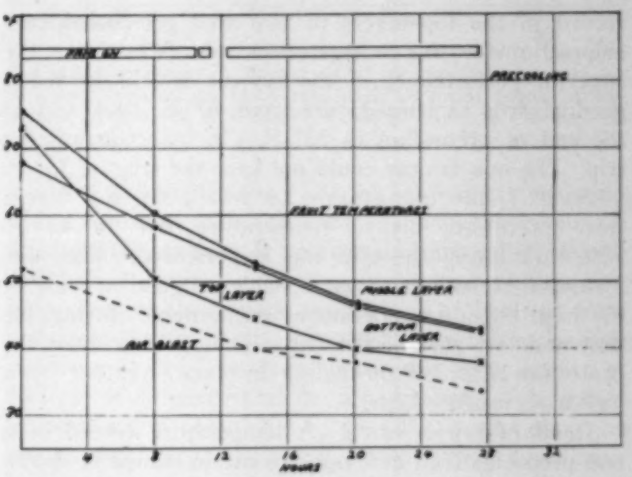

FIG. 3. Rate of precooling obtained in non-fan car of grapes with portable fans. Heavy load of grapes (34,000 pounds).

high rate, equivalent to 1½ tons per hour for short periods when the loads were hot, and ½ ton per hour average for 6 to 8 hours.

Refrigeration in Transit by Bunker Icing

Modified icing. A great number of refrigeration services are available for the protection of the lading from heat while in transit during warm weather. The most common practice is to use one of the bunker icing services, and the shipper may elect to have the cars pre-iced and re-iced at every icing station, these stations being about a day's journey apart. This is called

"standard refrigeration" and the charge is based upon the distance traveled and the commodity transported. Modified icing services are available at lower cost. They provide 1, 2, or 3 re-icings in transit, with or without replenishing the bunkers after loading. If a car of deciduous fruit is shipped from California to New York with two re-icings in transit after replenishing the bunkers at the first icing station (Rule 254), the cost is about $33.00 less than it would be for standard refrigeration service. Figure 4 shows the temperature

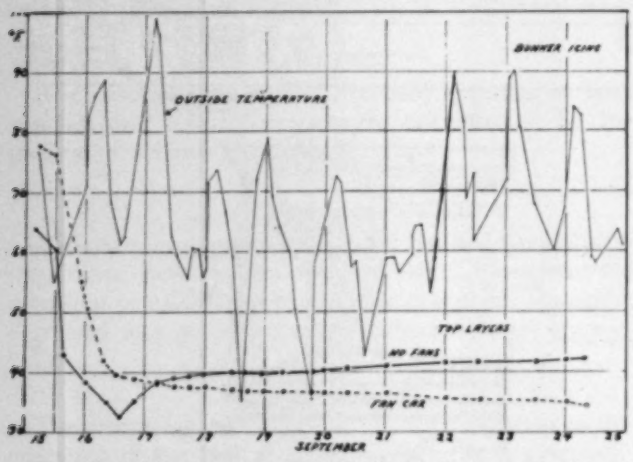

FIG. 4. Performance of precooled loads of grapes in fan and non-fan cars under bunker icing from Fresno, California, to New York, N. Y. Bunkers replenished after precooling. Re-iced at Ogden, September 19 and Chicago, September 23.

record in the top layers in two well pre-cooled cars shipped under this refrigeration rule *(8)*. Note the superior performance of the fan car which showed a gradual drop in temperature from 40° F. (4.4° C.) at the end of precooling to 35° F. (1.7° C.) during the trip. The non-fan car could not keep the fruit at 33° F. (0.56° C.), the temperature to which the top layers were precooled, and a temperature rise to 42° F. (5.6° C.) duing the trip was experienced. The performance of both cars was considered good in view of the high outside temperatures encountered during the first and last part of the trip. The records show the protection afforded the lading in warm weather by a well iced, insulated car.

Standard refrigeration. A temperature record of a non-precooled load in a non-fan car in transit is shown in Figure 5. Note the typical wide spread in temperature between top and bottom layers. This illustrates the inadequacy of natural convection as a means of air circulation. Slow cooling of top layers is another weakness of this system which relies upon a temperature difference, top to bottom of the car, for air movement. Three to four days are usually needed to bring top layers to 50° F. (10° C.) if the lading is moderately warm when loaded. Precooling was the remedy for this and it made possible a single re-icing in transit instead of daily re-icings. The savings amounted to $52.00, less a $20 to $25 cost for precooling.

Bottom layers of fruit are well refrigerated in non-fan cars because that is where the cold air from the bunker is expended. As might be expected, fan cars

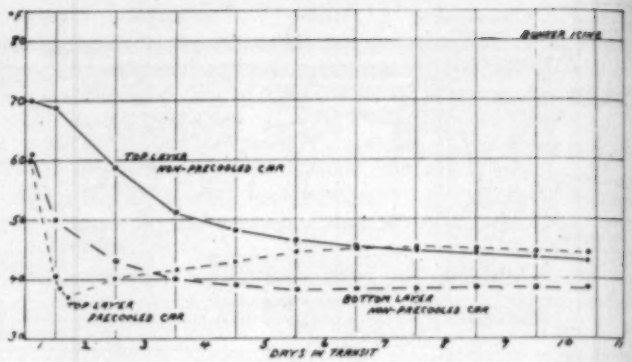

FIG. 5. Performance of non-fan cars with non-precooled and precooled loads of grapes from Fresno, Calif., to New York, N. Y. Bunkers re-iced daily in non-precooled shipment and on 5th day only in precooled car.

have not been a substitute for precooling, because car movement is not continuous enough during the first 24 hours after loading to provide sustained air circulation *(1)*. A more dependable practice is to operate the car fans with electric motors at the loading point until the load is cooled to about 40° F. (4.4° C.) before the car is released for shipment.

Standard refrigeration, salt, fan cars. Some perishable commodities, such as cherries and berries, need all the refrigeration that can be given them without danger of freezing. Fan cars and judicious salting of the ice provide a means of doing this *(6)*. Figure 6 is a record

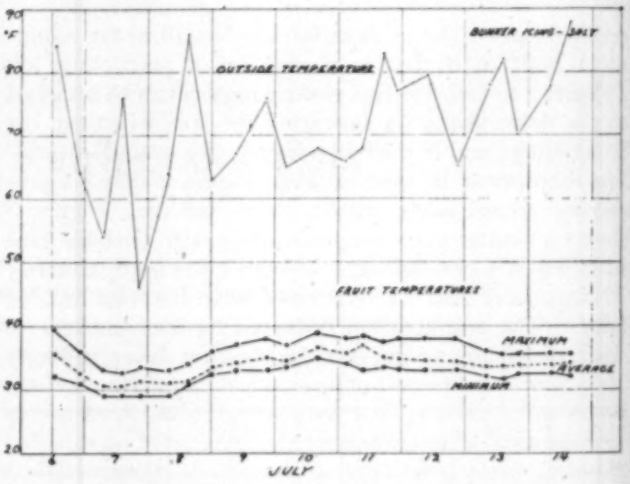

FIG. 6. Performance of fan car under ice and salting service. Precooled cherries shipped from Wenatchee, Wash., to New York, N. Y., with bunkers initially iced and re-iced daily; salted in amounts equaling 3 percent of the ice supplied initially and at all re-icings. Gerhardt and Ryall, U. S. D. A.-H. T. & S. Rept. 173 WFE 66568—1946.

of a carload of cherries precooled to an average of about 35° F. (1.7° C.) and then shipped under standard refrigeration with salt added to the ice in amounts equaling 3 percent of the ice supplied for initial icing and re-icing. Note that minimum temperatures were about 28.5° F. (—2° C.) for the first and second day after loading due to the heavy salting (288 lbs.) given the ice after loading on July 6. The average fruit temperatures were held between 31 and 37° F. (—0.56 and +2.8° C.)

and were about 35° F. (1.7° C.) for most of the trip; these were considered very good.

Similar low temperatures of 35 to 38° F. (1.7 to 3.3° C.) were maintained in 4 experimental cars of prepackaged vegetables shipped from California to midwestern and eastern markets in September *(12)*. Precooling, use of fan cars, and applying a small amount of salt to the ice at one or two icing stations were the means employed to accomplish this.

Body Icing

Body icing is the general practice for such perishable vegetables as lettuce, carrots, broccoli, cauliflower, sweet corn, and spinach. This term refers to the blowing of crushed ice over the top of the load and in the channels between the crates. Before ice-crushers and slingers were developed for this purpose, blocks of ice were placed on top of the load and in recesses or "pigeon holes" left in the load. Crushed ice is also used in the packages of someof the top-iced vegetables, such as lettuce, carrots, and broccoli. Figure 7 shows the

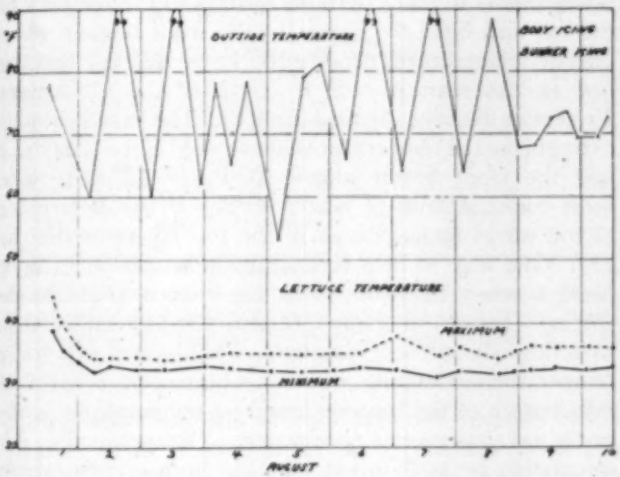

FIG. 7. Performance of refrigerator car under body icing. Lettuce shipped from Salinas, Calif., to New York, N. Y., package iced, body iced with 20,000 pounds, bunkers initially iced only. (Barger et al. A. A. R.-U. S. D. A. Rept. Test 18, Car A-1947.)

temperatures obtained in a carload of body-iced lettuce shipped from Salinas, California, to New York in August *(2)*. It also had the benefit of bunker ice. Note that the lettuce, which was 65° F. (18° C.) when packed, had cooled to 45° F. (7° C.) a few hours later, by the time the car was loaded. This was due to contact of the lettuce with crushed ice in the package. By the following day, commodity temperatures were 32 to 34° F. (0 to 1° C.) and throughout the rest of the trip they were 32 to 36° F. (0 to 2° C.) despite outside temperatures that were in the 90's for 4 days. Many thousands of cars of vegetables are shipped in hot summer months across the country iced in this manner, and the condition upon arrival is usually excellent because these low temperatures are maintained. This method of refrigeration requires a large supply of ice. As an example, the test car received a total of 45,000 pounds of ice of which 24,000 pounds was body ice, 10,300 pounds package ice, and 10,700 pounds bunker ice. This is a lot of ice to refrigerate 20,000 pounds of lettuce. By weighing the cars at the start and end of the trip, it was estimated that about half of the ice was melted in transit. That remaining in the package would give protection during marketing, but much of that left in the bunker and on top of the load could be considered surplus and of value only as a safety factor in case of delays or unusually warm weather.

Standard Refrigeration and Heavy Salting of Fan Cars for Frozen Food

Figure 8 shows a record of a frozen food shipment made in August and September from Seattle, Washing-

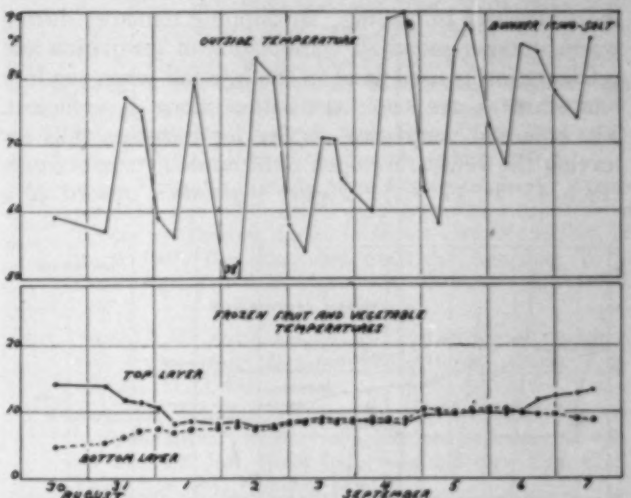

FIG. 8. Performance of fan car for frozen food; car pre-iced and salted to extent of 30 percent of ice supplied; bunkers re-iced and re-salted at same rate daily. Frozen beans, strawberries, raspberries, and spinach, Seattle, Wash., to Chicago, Ill. (Redit and Atrops. A. A. R.-U. S. D. A. Test 19, Car H-1947).

ton, to Chicago, Illinois *(10)*. A 40-foot car equipped with Preco fans and with 4 to 4½ inches of insulation was used in this test. It was pre-iced and salted several days before loading, salt being used in amounts equaling 30 percent of the bunker capacity. The bunkers were replenished with ice and re-salted twice before loading and were re-iced 7 times in transit, salt being applied at the rate of 30 percent of the ice supplied. Note that a temperature of about 10° F. (—12° C.) was about as low as could be maintained in transit *(10)*. Tests have been made with cars having as much as 6 to 7 inches of insulation, and a number of heavily insulated cars are in service for frozen food. Their chief advantage is in preventing warming up when standing; no lower transit temperatures have been possible with the heavier insulation. Trials have been made with a chemical, ammonium nitrate, that lowers the melting point of ice more than common salt does; but the cost was too great for the slightly lower temperature (6° to 8° F.) that it attained *(4)*. Other methods of getting lower temperatures for frozen food are being tried, such as continuous operation of car fans and the use of mechanical refrigeration. Before going too far in the direction of special equipment and added cost for the transit refrigeration of frozen food, the need for these lower

temperatures in transit must be established. A project sponsored by the Refrigeration Research Foundation is now under way at the Western Regional Research Laboratory of the U. S. Department of Agriculture in which a comprehensive study will be made of this question. Protection of frozen food from warming during loading and distribution at destination is part of the same general problem that needs attention.

Ventilation Service

Such commodities as tomatoes, which are customarily picked before they are ripe, bananas, and lemons are harmed by the usual refrigerator car temperatures. Tomatoes should not be held at less than 50° F. (10° C.) for any length of time, and bananas are even more sensitive to chilling. In shipping tomatoes during warm summer months a combination of ventilation and refrigeration is used; and in the late fall when outdoor temperatures are cool, ventilation alone is sufficient. The standard ventilation service for tomatoes calls for leaving the ventilators open until outdoor temperatures reach 45° F. (7° C.). Figure 9 shows a record of a

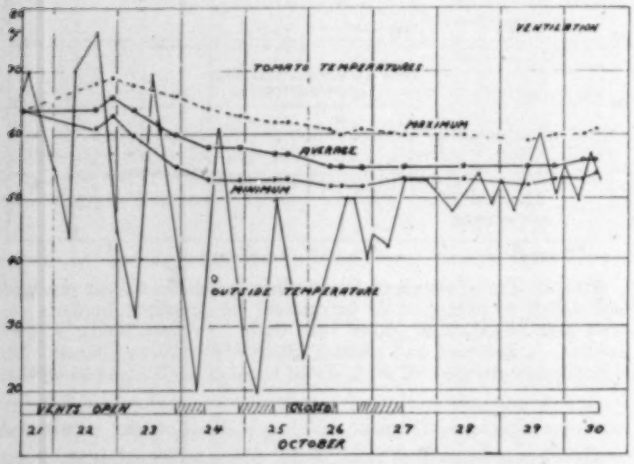

FIG. 9. Performance of refrigerator car under standard ventilation, vents open above 45° F. (7° C.). Tomatoes shipped fram Sacramento, Calif., to New York, N. Y. (Barger et al. A. A. R.-U. S. D. A. Test 21, Car 2, Oct. 1947.)

carload of tomatoes shipped under standard ventilation from California to New York late in October *(3)*. The tomatoes warmed a few degrees the day following loading but cooled thereafter because of the cold nights encountered in Nevada, Utah, and Wyoming. Although this was a fan car, the fans were not operated in order to compare it with one in which fans were used. There was no great difference in performance between fans and no fans, and this has been true in other tests under ventilation when no ice was used. If tomatoes are warm when loaded, say 75° F. (24° C.) or higher, the bunkers are usually iced at the first icing station to cool the load; and the vents may be closed a day or two thereafter and then opened and operated under standard ventilation. Fan operation in cars handled in this manner prevents bottom layers from becoming too cold and increases the cooling rate of the load.

The temperatures obtained in the car shown in Figure 9 were very satisfactory, for they prevented excessive ripening without stopping it completely. Forty to 75 percent of the tomatoes were still green when unloaded and the rest were firm ripe to turning in color.

Ventilation services for commodities that are not subject to chilling usually specify leaving vents open at temperatures above 32° F. (0° C.). A ventilation service has been worked out for late fall and winter shipments of non-precooled oranges from California that has been a good substitute for refrigeration *(7)*. Ventilators are left open to 20° F. (—6.7° C.) or even lower temperatures. This work has shown the need for knowing the temperature of the fruit within the car if advantage is to be taken of outside temperatures in ventilation. The same has been true for other fruits, such as apples and pears, which are often loaded into cars cold and then ventilated with air above 32° F. (0° C.).

Heater Service

The problem of protecting perishables from freezing during winter months is fully as important as refrigeration during warm weather. The common method of doing this is to place portable heaters in the bunkers of the car and light the heater in the front bunker when outside temperatures drop to 10° F. (—12° C.) and the one in the rear at —5° F. (—20.6° C.) ("Carriers Protective Service Against Cold"). The rear heater is extinguished at temperatures above —5° F. (—20.6° C.) and the front heater above 10° F. (—12° C.). The most common fault of heater service is the occurrence of too warm temperatures in the top layers of the car *(5)*. One way to help this situation would be to light heaters when temperature at the coldest place inside the car (bottom doorway) became too low rather than to follow the present practice. This would call for a temperature-indicating device. Thermostat control of heat output of the heaters, based on temperatures within the car, has given improvement in temperatures. Air circulation by built-in car fans has been of real benefit in preventing freezing and in preventing overheating of top layers. Figure 10 shows the record for a non-

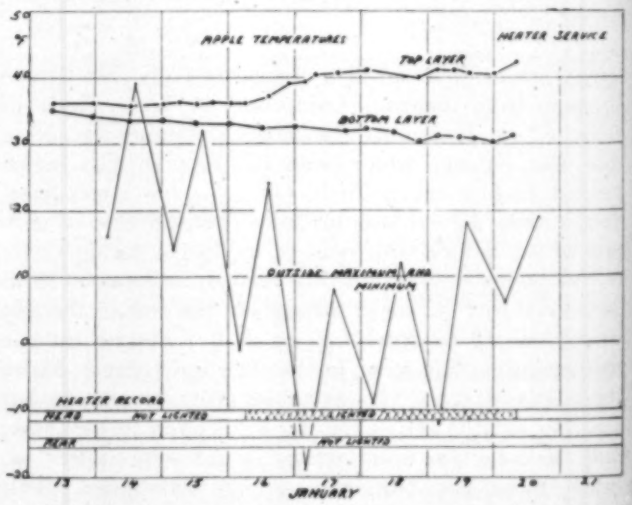

FIG. 10. Non-fan car under heater service with charcoal heaters thermostatically controlled. Apples shipped from Yakima, Wash., to Chicago, Ill. January, 1948. (Redit and Smith. A. A. R.-U. S. D. A. Rept. of Tests 22-27, Car 25 H.)

fan car under heater service with thermostatically controlled charcoal heaters *(11)*. The test was made in January, 1948, with apples from Yakima, Washington, to Chicago, Illinois. As indicated, outside temperatures of 0° F. (—17.8° C) or lower were encountered on 4 days with a minimum of —19° F. (—28° C.) on January 17. The rear heater was not lighted since —10° F. (—23° C.) was experienced for only a short time. Note the spread between top-layer and bottom-layer temperatures, despite thermostatic control of the heater. A better record was obtained in a fan car in which thermostatically controlled alcohol heaters were installed *(9)* (Figure 11). One of the advantages of fan cars is that the heaters may not have to be lighted during short periods of cold weather because of the mixture of air effected in the car by the fans. Note that in this test, the heaters were not lighted until the day following the cold weather of January 21. The general conclusion from two seasons' work on heater service conducted jointly by the Association of American Railroads and the U. S. Department of Agriculture is that regardless of the type of heaters used, fans were needed in the cars to prevent too high temperatures in the top layers of the load *(11)*.

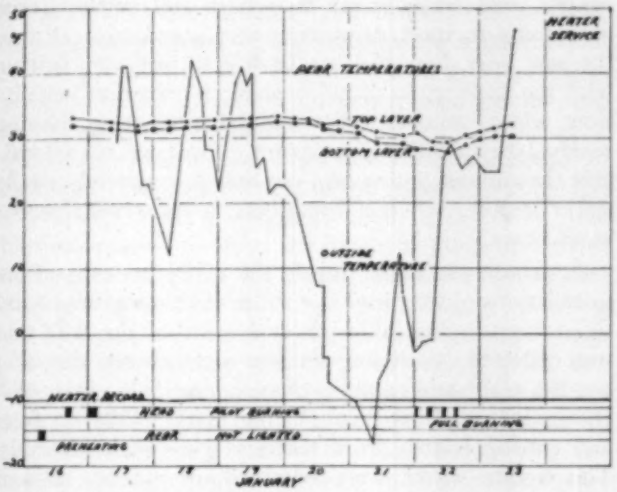

FIG. 11. Fan car under heater service with alcohol heaters thermostatically controlled. Pears shipped from Yakima, Wash., to Chicago, Ill. January. 1947. (Redit and Smith. A. A. R.-U. S. D. A. Tests 12-15, Car 26 B.)

Summary

The modern car, which has built-in fans, collapsible bulkheads, 3½ to 4 inches of insulation, and end bunkers holding 11,000 pounds of ice or more, performs well under most of the services for which it is used. As a precooler it will do a good job in about 24 hours; and under bunker refrigeration service it is capable of maintaining temperatures about 40° F. (4° C.) or less. By judicious salting of the ice, temperatures close to 35 to 36° F. (1.7 to 2° C.) can be maintained throughout the load. Under maximum salting for frozen foods, temperatures of about 10 to 15° F. (—12 to —9° C.) can be held in transit. Body and package icing, commonly used for leafy vegetables, give transit temperatures in the range of 32 to 36° F. (0 to 2° C.). When temperatures in the 50's or 60's are needed, for such sensitive commodities as tomatoes, ventilation or a combination of ventilation and refrigeration can be use. In cold weather ventilation is sometimes used instead of refrigeration. The chief problem in heater service is to avoid overheating, and use of fan cars and thermostatically controlled heaters has been of great benefit in this respect.

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Industrial and Legal Viewpoints

Sanitation Problems in the Fishing Industry[a]

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The author reviews progress in solving sanitation problems in the fishing industry and makes recommendations regarding further progress in this field.

A few years ago the Northeast Section of I. F. T. held an all day meeting. During the morning, several papers were presented in which the fishing industry was subjected to a considerable amount of criticism for laxity in sanitation. When the chairman suggested that the speakers would be happy to answer any questions which may have occurred to the audience, only one was asked, and that was whether or not fish would be served for lunch.

It is regrettable that some of the factors mentioned that day which prompted the lone question are still unsolved problems in the industry. On the other hand, considerable progress has been made on many of them and others have been solved in accordance with the best available technical information.

The fishing industry is no different than any other food industry as far as the usual every-day problems of sanitation are concerned. By "usual, every-day sanitation problems" we refer, of course, to such problems as good housekeeping and rodent and insect control. However, since the fishing industry is very close to being the oldest industry in the country, our plants have had slightly longer to weather the storms and our rodents and insects are slightly older and, consequently, slightly wiser.

The usual, every-day problems are just that: every-day problems; and, of course, only constant attention keeps them from becoming acute and serious. It seems, however, that in a good many cases we have looked at these every-day problems with a more technical approach than heretofore, and by thought, design and adaptation have changed every-day to once a week, once a month, or even a longer interval and, at the same time, have greatly improved the efficiency of the control over the problems. For example, several years ago, insect control meant only a skillfully planted rubber boot, and rodent control consisted of a well-aimed shovel in the hands of a dock worker. Today the insect control program in our industry consists of adequate screening when conditions permit and frequent periodic application by thoroughly trained personnel of modern insecticides such as DDT, Chlordane, Hydrogenated Rotenone and Pyrethrins, to name a few, combined with such materials and procedures as "aerosols" and "mist spraying." In rodent control work, we have been extremely successful with installations utilizing ANTU and, in the plant of Gorton-Pew Fisheries Company, Ltd., the rigidly controlled use of 1080 in certain localities of our buildings has given us success which was previously thought impossible to obtain.

[a] Presented before the Northeast Section, I. F. T., Boston, Mass., Feb. 7, 1949.

An important factor in any food processing plant is, as we all know, its water supply. We in the fishing industry are fortunate, that is, most of us are, in having one of the largest water supplies possible available right in our own backyard. Of course, we realize the limitations of this source of water and our obligations to the consuming public with regard to its use. For many years this company has chlorinated all of the salt water supply used freely in all its wharf and cutting room operations to meet drinking water standards. Within the past year, however, we have gone one step further with the application of an in-plant chlorination installation which automatically maintains a free chlorine residual beyond the break-point. Thus we have available throughout our system not only a completely sterile water supply, but one containing a bactericidal agent at all times.

A survey was made during the earlier months of the installation to determine the value of this treatment and the accompanying table presents some of the data that was collected. Sampling stations were chosen throughout the plant and samples of incoming fish, scaler discharge water, drips from cutting belts, swabs on belts and cutting boards were taken at two-week intervals. The counts which were obtained, of course, showed some variation, but, in general, after several samplings a definite pattern became noticeable. The survey was divided into three parts: a 6-sample period of Break-point Chlorination, with residuals of 5 to 10 p.p.m. during the day and 25 p.p.m. during the clean-up periods; a 6-sample period of Marginal Chlorination, with residuals of 0.1 to 0.2 p.p.m.; and a repeat period of the Break-point type. In order to compensate for the variations in counts which occurred in Station 1, which represents incoming fish from the boats, all of the Station 1 counts were considered equal to 1 and the

AVERAGES OF RATIOS OF STATION COUNTS TO INCOMING FISH

Station	Break-point Chlorination 5 p.p.m.	Marginal Chlorination 0.1-0.2 p.p.m.	Break-point Chlorination 5 p.p.m.
1	1.0	1.0	1.0
2	0.06	20.2	0.022
3	2.3	295.0	0.09
4	0.4	39.2	0.14
5	0.5	43.6	0.28
6	1.1	191.0	0.67
7	3.3	20.5	0.16
8	0.35	216.0	0.32
9	1.1	29.8	0.17
10	4.5	29.7	0.63

Station 1—Incoming fish
Station 2—Drip from scaler
Station 3—Drip from belt leading from scaler
Station 4—Swab of same belt
Station 5—Drip from far end of same belt
Station 6—Drip from cutting belt nearest scaler
Station 7—Swab of same belt
Station 8—Drip from far end of same belt
Station 9—Swab of cutting bench
Station 10—Finished fillet from brining tank

corresponding counts for each sampling station were computed as ratios to this figure. This table simply shows the averages of these ratios to incoming fish counts. In general, the ratios during Break-point periods are less than 1, indicating considerable bacteria destruction, while during Marginal Chlorination periods, the figures indicate clearly that build-ups in counts throughout the room were common.

Apart from the bacteriological data which was obtained during this survey, two other direct benefits from the use of break-point chlorination were noted. The first was marked reduction of odors in the areas serviced by the salt water supply and the second was the elimination of slime on working surfaces which come in contact with this water. There is no question that both of these benefits tend toward the aesthetic side, but the presence of any off-odors in a plant is not a healthy condition nor conducive to a good product; furthermore, its effect on customers and guests who are visting is not desirable.

C. H. Castell of the Fisheries Research Board of Canada in "Progress Report of the Atlantic Station No. 40" reports that it required about 200 p.p.m. free chlorine residual to affect the flavor of fillets and about 2000 p.p.m. to affect the color. Since we were operating with a residual of 5 to 10 p.p.m. while operating and 25 p.p.m. during clean-up periods, we were confident that no harmful effects would result from this work and we are in complete agreement with the statement by Mr. Castell that, "It is safer and cheaper to increase the keeping quality of fillets by keeping the bacteria from getting on them by having sanitary surroundings, rather than by trying to destroy the bacteria on the fish by chlorinating them."

Another source of trouble in our industry which is somewhat allied to water treatment and which must be very carefully watched, is brine tank contamination. The mechanical action of flushing of fillet surfaces in brine prior to packaging and freezing very quickly builds up high bacterial counts in the brine as well as the dissolved and suspended protein concentration. For some time the only control of this problem was change of the brine at frequent intervals. Temperature control of the brine is an aid toward solving this problem, but it is definitely not the complete answer; consequently, a great deal of work has been done on this problem in recent years and is continuing. Chlorination has proven to be effective to some degree, but in many brine systems it is not completely satisfactory because residuals are difficult to maintain at predetermined levels. This difficulty arises because of the large amounts of organic materials present in brining systems, and the lack of a constant flow of fillets to and from a good many of them. Some work has been done on the use of quarternary ammonium compounds in connection with this problem, but these substances, too, have drawbacks. There is no doubt of their effectiveness in the sanitizing of the brine system, but difficulties in method of application are still bothering us to some extent. The most recent approach to the solution of this problem is the use of ultraviolet radiation combined with filtration but, here again, although we are able to demonstrate effectiveness, difficulty in adaptation of design of equipment is still a source of trouble. It appears, however, that before very long either one or combinations of more than one of these methods of treatment will give us brine to use for much longer periods, with its quality level, from the standpoint of sediment and bacteriological condition, raised to a much higher plane than has heretofore been reached.

General cleaning methods within our industry have, like the other factors mentioned above, also been changed to some degree. The packing of fish products is, by nature, not an easy job from the standpoint of wetness, waste and trimmings. To quote my good friend, Mr. John Kaylor, "One can no more fillet fish without producing some scrap than one can saw a board without producing sawdust. But, the presence of these bits of fish accumulated to an unnecessary degree or left for long periods without removal is an unsanitary practice and is not to be tolerated." The cleaning of equipment in fish processing plants is still, primarily, a scrub and rinse project, but some of the scrubbing necessary has been reduced, by the use of modern detergents, wetting agents and salt water soaps, while the over-all efficiency of the cleaning program has been increased. Since in our industry the removal of protein is the primary problem, some detergents are valuable and others are worse than useless. Considerable attention is due the temperature of the water that is used. Warm water is sometimes valuable, at other times hot water coagulates finely divided protein so severely that the removal job becomes more difficult than if heat were not applied. Live steam for some applications does a superlative job, but if thermophilic organisms are present, then warming up the equipment during a clean-up prior to an 8 or 10 hour shutdown is apt to cause difficulty. Considerable success has been attained through the use of a high pressure pump which supplies water at 500 pounds per square inch, and at that pressure the material clinging tenaciously to the equipment is rather easily dislodged and then flushed away with large volumes of water at normal pressures.

Advancement in cleaning methods is, of course, also due to improvement in equipment design. In many of the plants in our industry one can still find wooden equipment of varied ages; but, also, one can find that the use of galvanized iron and, best of all, the use of stainless steel is becoming more common than in the past. The corrosion problem in the fisheries is probably the most severe of any food industry with salt, water and salt air always present. Corrosion is, of course, an enemy of good sanitation practice, since nothing can be more difficult to keep clean than an apparently smooth surface that is pitted. The intelligent use of the correct type of stainless steel for each individual application has done much to improve the over-all sanitary condition of our industry. There is still much to be done along this avenue, however, before we will be able to rest even for a moment.

Any discussion of the sanitation program in a food industry should include a few remarks about the personal habits of the people employed in it. In many of our plants you will see workers who are neatly attired with suitable coverings for the head and hands. In addition, physical examinations are a prerequisite to

employment in a good many companies. All other efforts to improve sanitation can be nullified unless an adequate program of employee education is maintained.

In this discussion of sanitation and fish processing, past and present have been considered, and this paper should be brought to a close with just a glimpse into the possible future. It is very certain that within a reasonable length of time our industry will undergo a drastic change, and when that change occurs, we will find that definite standards have been established for factors which, today, seem intangible. Most technologists in the industry are united in the belief that it is much wiser to develop these standards; actually, we are welcoming the opportunity to do so and a good deal of the technical work in the industry is aimed at just these very problems. For example, which are the organisms that give us the most trouble and what is their resistance to the known germicidal agents? What does an actual bacteria count of 500, 5000 or 5,000,000 on equipment mean with respect to the keeping qualities of our products? How does the presence of germicidal agents incorporated in the ice we use aboard our vessels affect the sanitary characteristics of these vessels and, consequently, the quality of our merchandise? What cleaning methods in use at sea are important toward the maintenance of conditions we desire and how will the addition of chlorine or quarternary compounds to the boat's own supply of water affect these same conditions? How can we ourselves, best inform our customers of those brands and products that represent organizations which are making every effort to continually improve their techniques and, lastly, how can we, ourselves, best inform customers of those brands and products that represent organizations which are content to 'just get by'?

These questions, and these are but a few, represent the challenge which we in the fish processing industry are attempting to meet.

Notes and Letters

Volatile Fruit Concentrates Now Free from Tax

To the Editor, Food Technology:

Because of the active commercial interest in our process for production of volatile fruit concentrates, we have endeavored to keep industry promptly informed of any significant developments which pertain to this subject.

As these volatile fruit concentrates are produced by distillation and generally contain a half percent or more of alcohol, they have been subject to the usual taxes and restrictions on such products. However, on August 17 a bill, H. R. 5270, which exempts volatile fruit concentrates of reasonable alcohol content from certain taxes and other restrictions, was signed by the President and became Public Law 240, 81st Congress. This Act amends subchapter E of chapter 26 of the Internal Revenue Code.

The regulations pertaining to this amendment define the limits of alcohol content and the conditions under which volatile fruit concentrates may be produced and used. These regulations have now been published in the Federal Register of September 27, 1949, pages 5869 to 5879, inclusive. Copies of this issue may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. The regulations became effective on the date of publication in the Federal Register.

Inquiries concerning the new code should be addressed to Mr. Carrol E. Mealey, Deputy Commissioner, Alcohol Tax Unit, Treasury Department, Washington, D. C.

P. A. WELLS, Director
Eastern Regional Research Laboratory
Bureau of Agricultural and Industrial Chemistry
United States Department of Agriculture
Philadelphia 18, Pennsylvania

Oil Chemists Told Latest Developments in Monoester Field

It was recently reported to the American Oil Chemists' Society in Chicago that glyceryl monoesters of fatty acids, widely used during the past decade as baked-goods "improvers" and cosmetic emulsifiers, can now be prepared in much purer and more potent form than has been available in the past. It was announced that the purified distilled "monoglycerides" are now commercially available with a minimum monoester content of 90 percent. This statement is significant in view of the fact that similar mixtures previously on the general market have contained from 30 to 50 percent monoester.

Addition of only 1¼ percent of one of the new distilled "monoglycerides" to the shortening of an experimental sugar-rich "gold" cake batter has a greater effect in increasing the volume of the finished cake than addition of 10 percent of the older type of monoglyceride, although, for best results in texture and other cake properties, full proportions of normal shortening must still be used, it was stated. It is believed that the new product will have at least four times the activity of the older material in other types of cakes and baked goods. Analytical data are: glycerol content, 2.5 percent max.; free fatty acid content (as oleic), 1.0 percent max.; saponification value, 150-160; iodine value, 75-85; color (5¼" Lovibond), 15Y/1.5R max.; M. P., 52° C., 125.6° F. (approx.); specific gravity, .93 at 60° C.

The enhanced properties of the distilled monoesters are primarily due to the high monoester content, but additional benefits are believed due to the absence of diesters, metallic soaps and residual catalyst, and to the low content of glycerol and free fatty acids. Previous commercial methods have been unable to separate all these substances effectively from the surface-active monoesters.

POE, C. F., 71
Pollution, stream, 323
Population growth and the Institute of Food Technologists, 319
Position of food technologists in national emergency, 37
Poultry
aging, freezing and thawing effect on palatability of eviscerated, 156
flavor constituent from meat, 118
POWERS, M. J., 213
Precautions for methyl bromide fumigations, 114
Prediction of thiamine and ascorbic acid stability in stored canned foods, 148
Preparation of sterile fish muscle press juice for chemical and bacteriological studies, 274
PRESCOTT, S. C., 3
Preservers' stake in uniform pectin grading, 28
Pressure hydrolysis of proteins, 51
PRINCE, R. N., 258
Procedure for quantitative estimation of Salmonella in dried egg products, 172
Process evaluation, 116, 126
Processing frozen orange juice concentrate, 395
PROCTOR, B. E., 387
Production of mushroom mycelium by submerged propagation, 355
Prooxidant effect of ascorbic acid and cysteine in aqueous fat system, 152
Protein
influence of heat-processing on functional and nutritive properties of, 57
"in vitro" pancreatic hydrolysis rate, 170
Proteins
determination of biological value with T. geleii H, 289
isolation from fruit by foam fractionation, 198
pressure hydrolysis of, 51
Prune skins, observations on toughness and microscopic nature, 244
Purees, studies on frozen fruit and vegetable, 100

Quality
control in frozen poultry (following page 74), 7
in foods, 179
of frozen bakery products, 160
of frozen cooked foods, 187
rational grading of food, 252
retention in sugar affected by hygroscopicity and other factors, 347
Quaternary ammonium compound in sanitizing glass containers, 304

RAMSEY, T. H. (following page 74), 7
Rationalizing failure of a quaternary ammonium compound to detect true germicidal activity in sanitizing glass containers, 304
Recent developments of practical significance in the field of pectic enzymes, 94
Reflectometer determination of color of unclarified juices, 274
Refrigerator car performance tests, 410
REICH, G. T., 383
Relation of spray residue problem to food processing 339
REED, J .M., 213
Research
food and nutrition survey, 36
frozen food industry, 112
Riboflavin-enriched mares' milk, loss of reduced ascorbic acid from, 277
RITTENBERG, S. C., 201
ROBERTSON, W. F., 228
ROCKLAND, L. B., 289
Role of monosodium glutamate in seasoning (following page 74), 7, 351
ROSE, G. A., 381
ROSOFF, H., 100

Salmonella in
dried egg products, estimation, 172
egg albumen, destruction of, 180
Sanitation problems in the fishing industry, 416
SCARBOROUGH, D. A., 152
SCHNEIDER, W. K., 192
SCHOPMEYER, G. E., 263
Science on trial, 316
Scientific society and technical progress, 251
SCOTT, Don, 76
SEAGREN, G. W., 192
Seasoning, role of monosodium glutamate in, (following page 74), 7, 351
SHACKELFORD, C. H., (following page 278), 7
SHEARER, P. S., 284
Sirup treatment of apple slices for freezing preservation, 404
SLOSBERG, H. M., 180
SMITH, Charles L., 313
SMITH, E. E., (in section following page 378), 9
SMITH, Jeanne, 184
Sodium fluosilicate—uses in food industry (in section following page 354), 16
SOMERS, I. I., 213
SORBER, D. G., 359
SPEISER, R., 90
SPELMAN, A. F., 269
Spoilage, an investigation of mayonnaise, 201
Spray residue problem in food processing, 339
Squash, comparison of light and dark storage of butternut, 269
Stability of fat peroxides, 206
Stains, analysis, used for microscopic enumeration of bacteria in milk, 324
Standardization of pectin, need for, 34
STEINBERG, M. P., 367
Stephen M. Babcock award presentation to Clarence Birdseye, 319
STEPHENSON, R. M., 364
STEWART, G. F., 156
Storage
of butternut squash in light and dark, 269
studies on active dried bakers' yeast, 234
STRACHAN, C. C., 327
Stream pollution, 323
STROHMAIER, Leonora Hohl, 100, 244
Student and future military considerations, 111
Studies
of commercial warehouse temperatures with reference to the stability of vitamins in canned foods, 292
on the darkening of orange juice, 373
on the rate of "in vitro" pancreatic hydrolysis of protein, 170
Sucrose sirups, rapid determination of percent inversion in, 258
STUMBO, C. R., 116, 126
Sugar hygroscopicity and other factors affecting retention of quality, 347
SUGIHARA, James, 370
SUGIHARA, T. F., 355
Survey of food and nutrition research, 36
Survival of yeasts in orange beverage base, 196
Swordfish, some aspects of trimethylamine formation in, 269

TANNER, F. W., 179
Taste
panels, 131
perception and taste preferences of the consumer, 136
Technical progress and the scientific society, 251
Thermal processes for foods, evaluation, 126
Thiamine and ascorbic acid stability in stored canned foods, 148
TINKLIN, G. L., 184
TOWNSEND, C. T., 213
Trimethylamine formation in swordfish, 269

Ultraviolet light, effect on keeping quality of frozen pork, 4
Use of
ion exchangers in by-product recovery from pineapple waste, 40
liquid sugars in freezing of apricots, peaches and nectarines, 8

VAIL, G. E., 184, 206
Vegetables, effect of desiccation on frozen, 307
Vitamins in canned foods, stability at commercial warehouse temperatures, 292
VOLZ, F. E., 4, 307
von LOESECKE, H. W., 323
VORIS, L., 36
VUCASSOVICH, M. P., 14

WATT, D. B., 206
WATTS, B. M., 152, 332
WESTERMAN, B. D., 184
WETHERBEE, R. T., 269
What research means to the frozen food industry, 112
WHITCOMBE, J., 164
WIEGAND, E. H., 274
WILBUR, J. S., 359
WINDER, J. D., 367
WODICKA, V. O., 148
WOLLAM, M. K., 260
WOODMANSEE, C. W., 23, 82
World health and food technology, 147
WORTHINGTON, O. J., 274
Yeast
storage studies on active dried bakers', 234
survival in frozen fermented and unfermented doughs, 139
Yeasts, survival in orange beverage base, 196
Yield of edible portion of chicken and various meats cooked by different home methods, 263

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